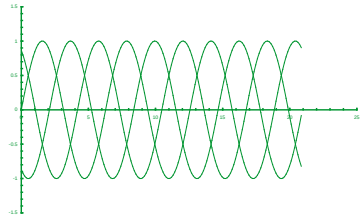
Power Quality & Energy Efficiency Solutions

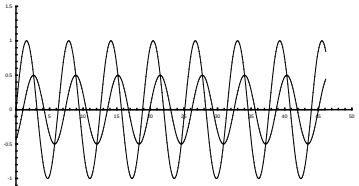
2013 PLUG

Schneider Electric

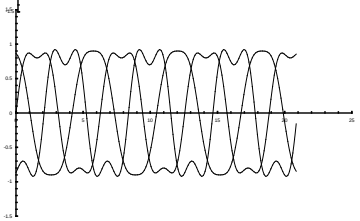
The ideal voltage supply does not exist



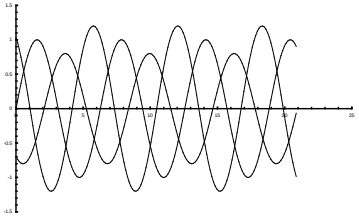
3-phase balanced



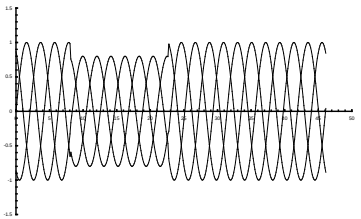
Power factor



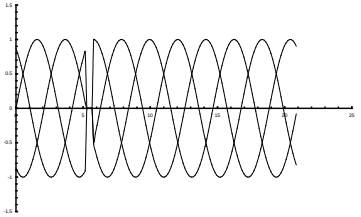
Harmonics



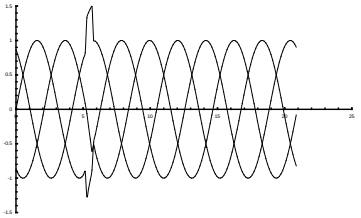
Phase unbalanced



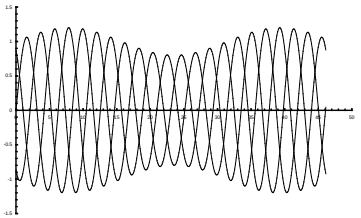
Sags/swells
Overvoltage



notches



Spikes



Flicker

Schneider Electric

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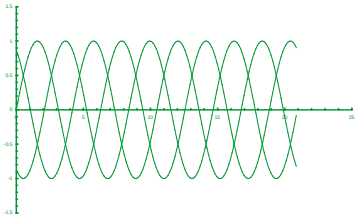

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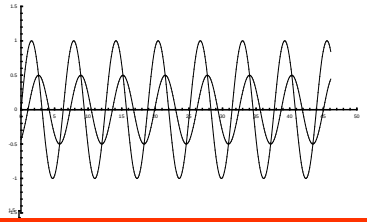
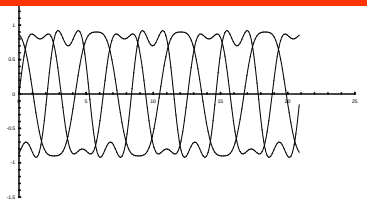


Power Factor



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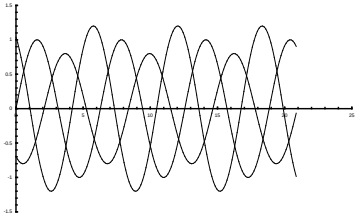

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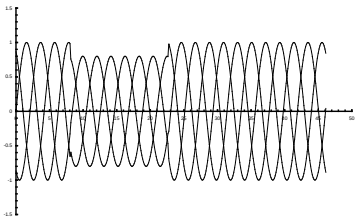

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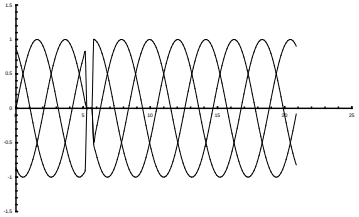

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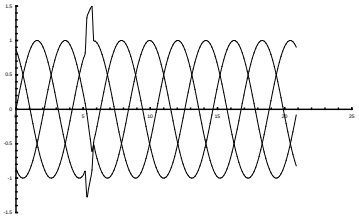

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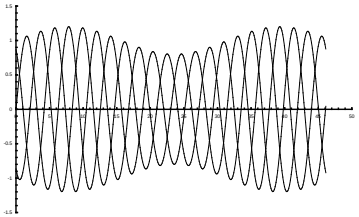
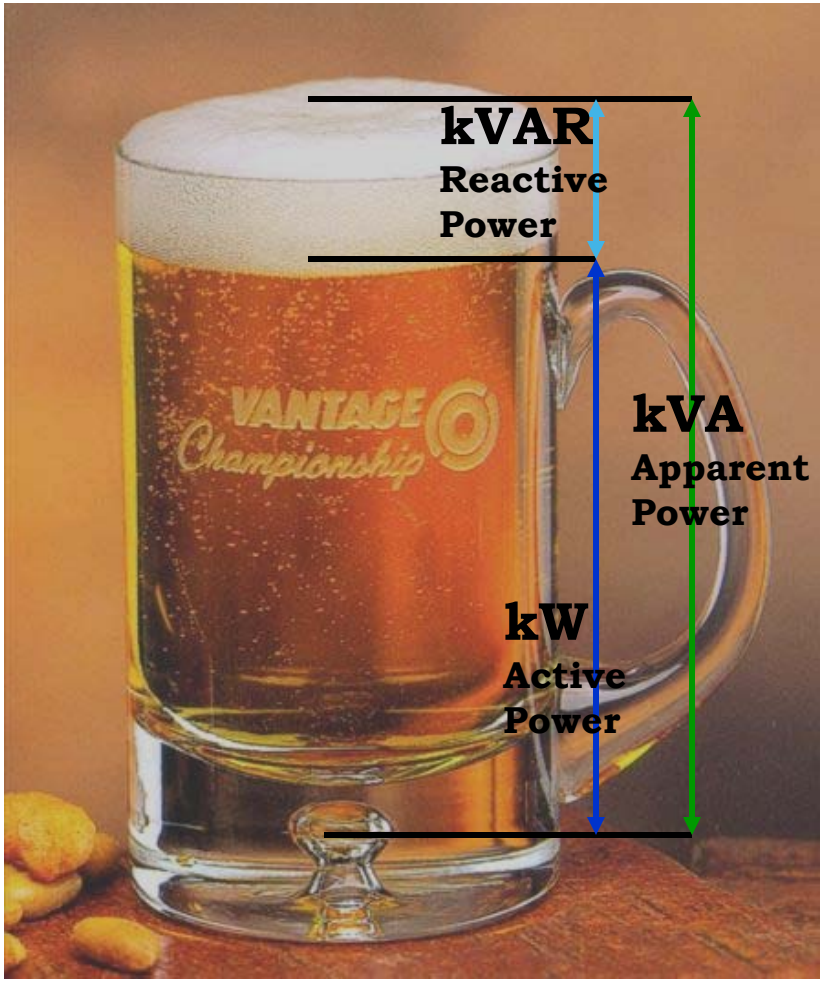


Flicker

Power Factor: The Beer Analogy



Mug Capacity = Apparent Power (KVA)

Foam = Reactive Power (KVAR)

Beer = Real Power (kW)

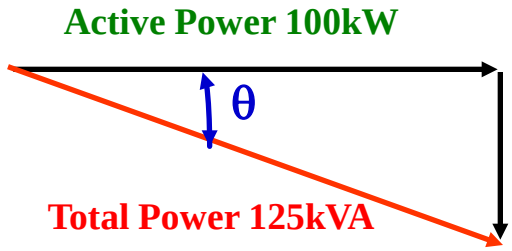
$$\text{Power Factor} = \frac{\text{Beer (kW)}}{\text{Mug Capacity (KVA)}}$$

Capacitors provide the Foam (KVAR), freeing up Mug Capacity so you don't have to buy a bigger mug and/or so you can pay less for your beer !

Schneider Electric

Power Factor

- If you had a load in a paper mill that was operating at 100 kW and the Apparent Power consumed was 125 kVA, what is the Power Factor?

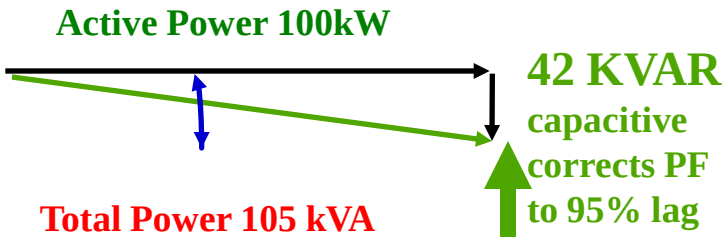


$$\text{Power Factor} = \frac{\text{Active (Real) Power}}{\text{Total Power}}$$

$$= \frac{100\text{kW}}{125\text{kVA}}$$

$$= \text{Cosine}(\theta) = .80$$

- If we add capacitance to this system and raise the power factor to 95% or 0.95, it would only require 105kVA to supply the same load. That is a reduction of 20%!



$$.95\ \text{pf} = \frac{100\text{kW}}{\textit{Total Power (kVA)}}$$

$$\text{Total Power} = \frac{100\text{kW}}{.95}$$

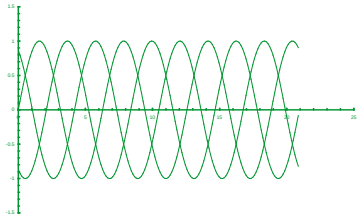
$$= 105\text{kVA}$$

Energy Efficiency with PFC

- **Power factor correction reduces utility costs**
  - Reactive power no longer in network
  - Utility cannot invoice for reactive power
- **Power factor correction reduces loading on DE & TFR**
  - Power generation and transmission network does not provide apparent power, S, transmits active power, P, only
  - With local correction, the size of utility and end user distribution equipment optimized *(reduction of distribution equipment size 20 to 40% = more capacity for kW only)*
- **Power factor correction**
  - Power losses minimized I^2R losses
  - Improve electrical system voltage (less downtime)

Schneider Electric

The ideal voltage supply does not exist



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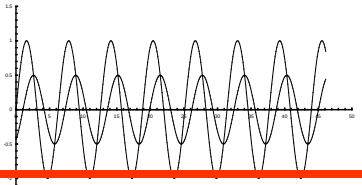

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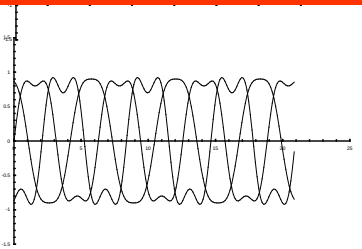
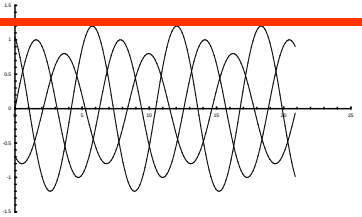


Harmonics



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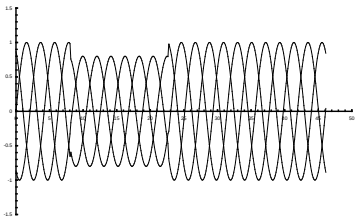

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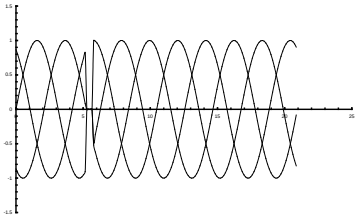

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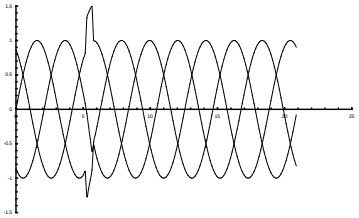

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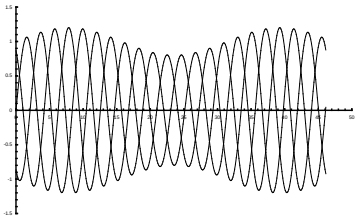
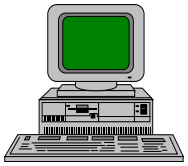


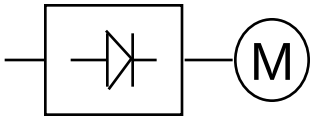
Flicker

Harmonics: Fundamentals

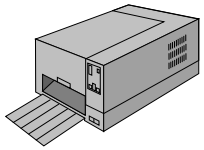
●What produces “Non-linear” current?



- Computers

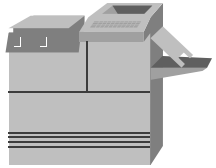


- Variable Frequency Drives

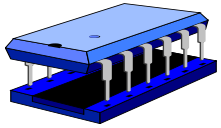


- Fax Machines

- Electronic Ballasts



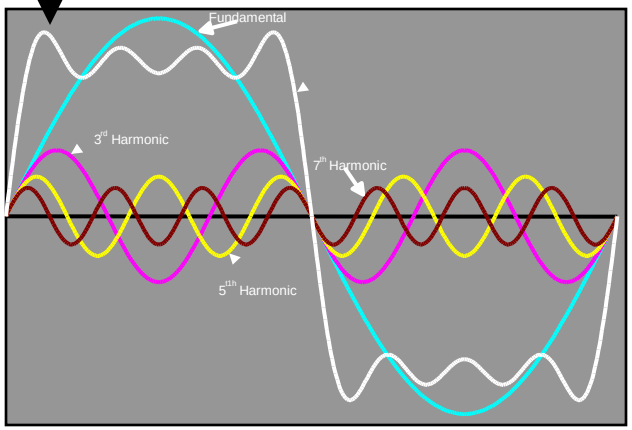
- Copiers



- **Almost anything electronic**

Harmonic Basics

Waveform seen with oscilloscope



Harmonic	Frequency Sequence	
1	60Hz	+
2	120Hz	0
3	180Hz	0
4	240Hz	0
5	300Hz	-
6	360Hz	0
7	420Hz	+
:	:	:
19	1140Hz	+

- What are harmonics?
  - A harmonic is a component of a periodic wave having a frequency that is an integer multiple of the fundamental power line frequency
  - Proliferation of power semiconductor devices
    - Converts power (AC to DC)
  - Characteristic harmonics are the predominate harmonics seen by the power distribution system
    - Predicted by the following equation:

$$H_c = np \pm 1$$

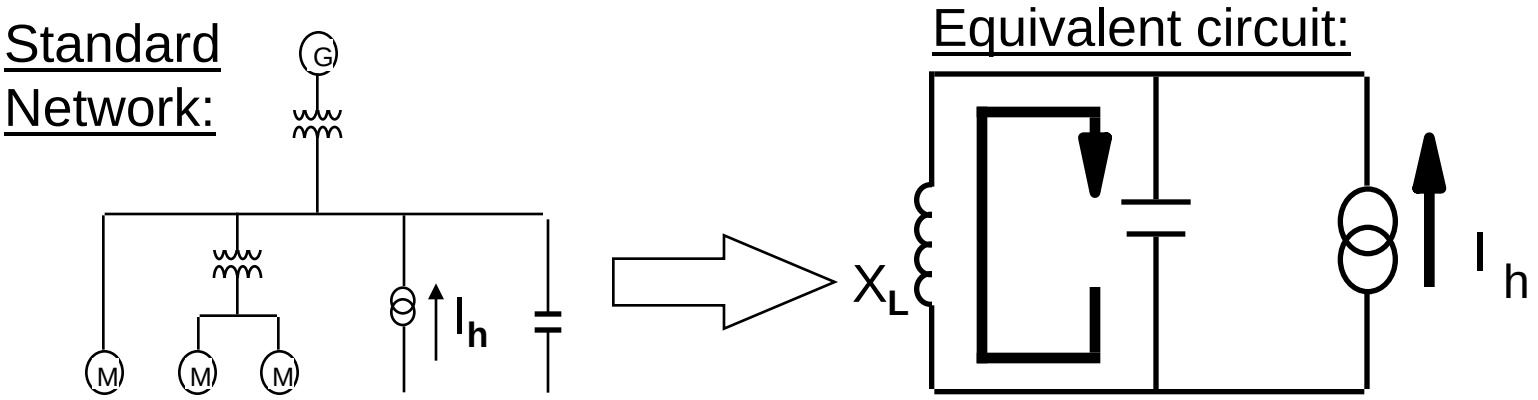
  - H_C = characteristic harmonics to be expected
  - n = an integer from 1,2,3,4,5, etc.
  - p = number of pulses or rectifiers in circuit

Schneider Electric

- Amplitude is inverse of order (perfect world)

How Harmonics Affect Capacitors:

- **How Capacitors "Tune" a circuit:**



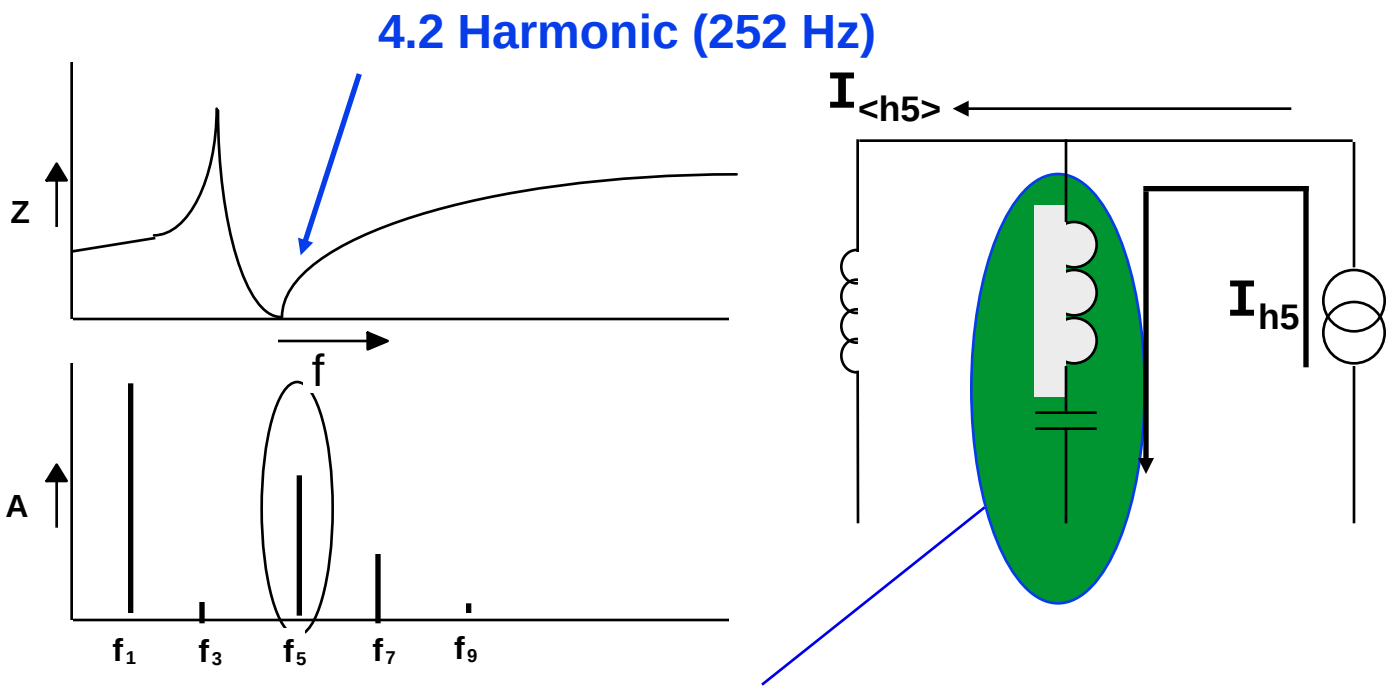
$$fr = 60 \times \sqrt{\frac{kVA \times 100}{kVAR \times Iz}}$$

e.g. 1500 kVA
225 kVAR
5.55% Iz

$$\therefore fr = 60 \times \sqrt{\frac{1500 \times 100}{225 \times 5.55}} = 660hz = h_{11}$$

Power Factor Correction With Harmonics:

- **De-tuning a network:**
  - "Force" the resonant point away from naturally occurring harmonics



We control the impedance of these two elements

Harmonic Standard

ANSI Standard IEEE 519-1992

- Chapter 11
  - Addresses THD(V) delivered by utility to user
  - THD(V) must be < 5% [< 69 KV systems]
  - THD(V) must be < 3% [< 69 KV systems] for special application; example Airport and Hospital
- Chapter 10
  - Defines the amount of **TDD** a user can cause
  - Based upon size of user in relation to power source
  - Table 10.3 for systems < 69 kV
  - Defines limits for voltage notches caused by **SCR rectifiers** – Table 10.2
- Defines PCC (point of common coupling). Basically where other customer are connected.

Harmonic Standard

IEEE 519-1992

- Defines current distortion as **TDD**
  - Total Demand Distortion
    - Largest amplitude of harmonic current occurs at maximum load of nonlinear device – if electrical system can handle this level, it can handle all lower amplitudes
    - *Note: the definition of TDD is harmonic current distortion in % of maximum demand load current (15 or 30 min demand). To simplify the discussion, we use full load current here.*
    - Effective meaning for current distortion
- Defines voltage distortion as THD
  - Total harmonic voltage distortion
- Does not use THD(I)
  - Total harmonic current distortion
  - Instrument measurement (instantaneous values)
  - Uses measured load current to calculate THD(I)

Harmonic Standard

- THD(I) versus TDD, example with VFD load

Max level of harmonic current occurs at full load level

	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.

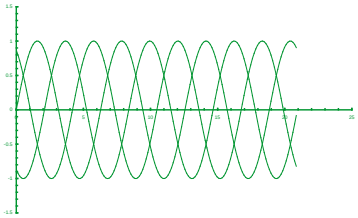
Active Harmonic Filter

208 – 480 VAC

600 – 690 VAC

Schneider Electric

The ideal voltage supply does not exist



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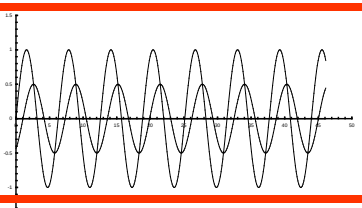

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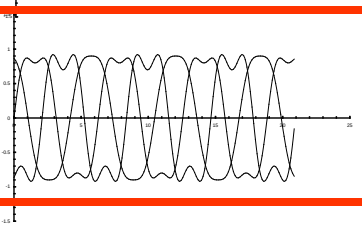

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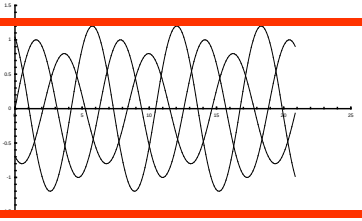

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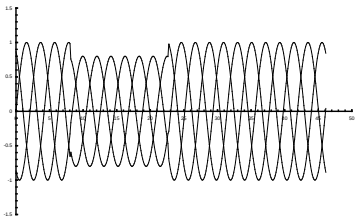
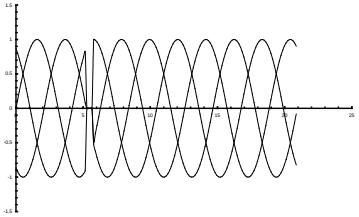
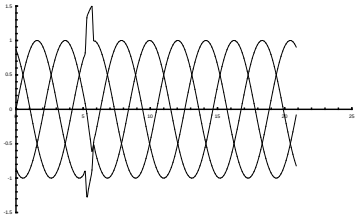


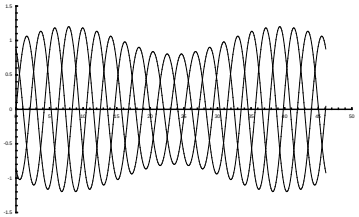
Sags/swells
Overvoltage



notches



Spikes



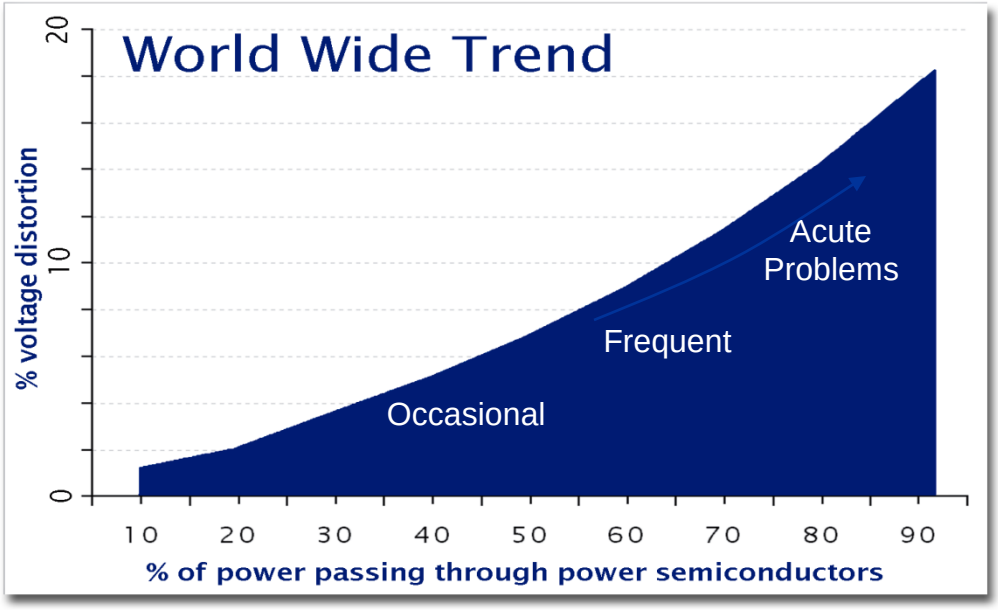
Flicker

Should we be concerned about harmonics ?

- “ We don’t have harmonics in our facility ”
- “ Our devices don’t cause harmonics “
- “ Harmonics have never been a problem before…”

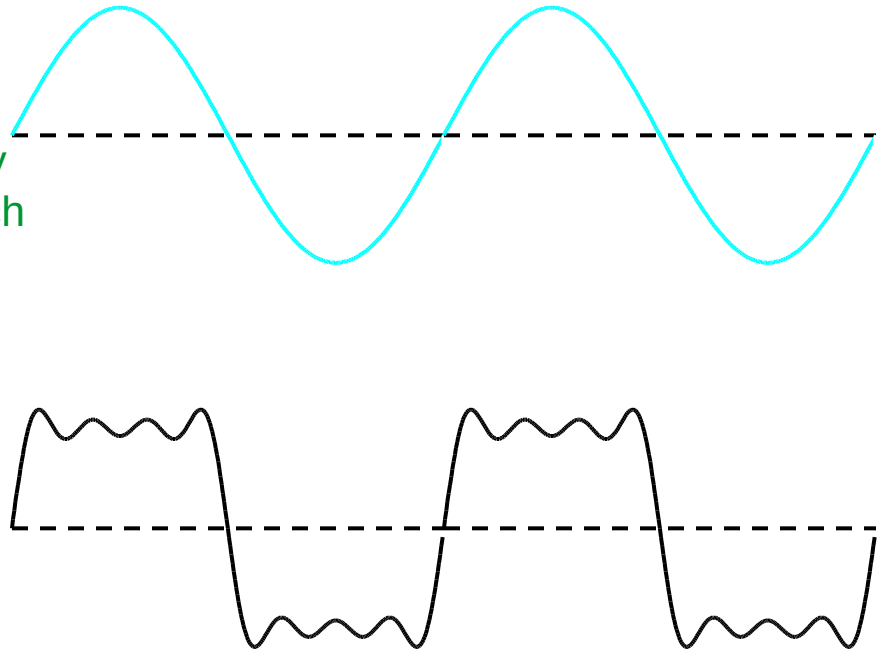
How common is this power quality problem?

- Over $20 billion of power semiconductor products installed annually
  - computers and peripherals, IT devices, VFD, UPS, and industrial power supplies
- 35-40% of all power flows through power semiconductors today.
- Growth to 70% in the next few years



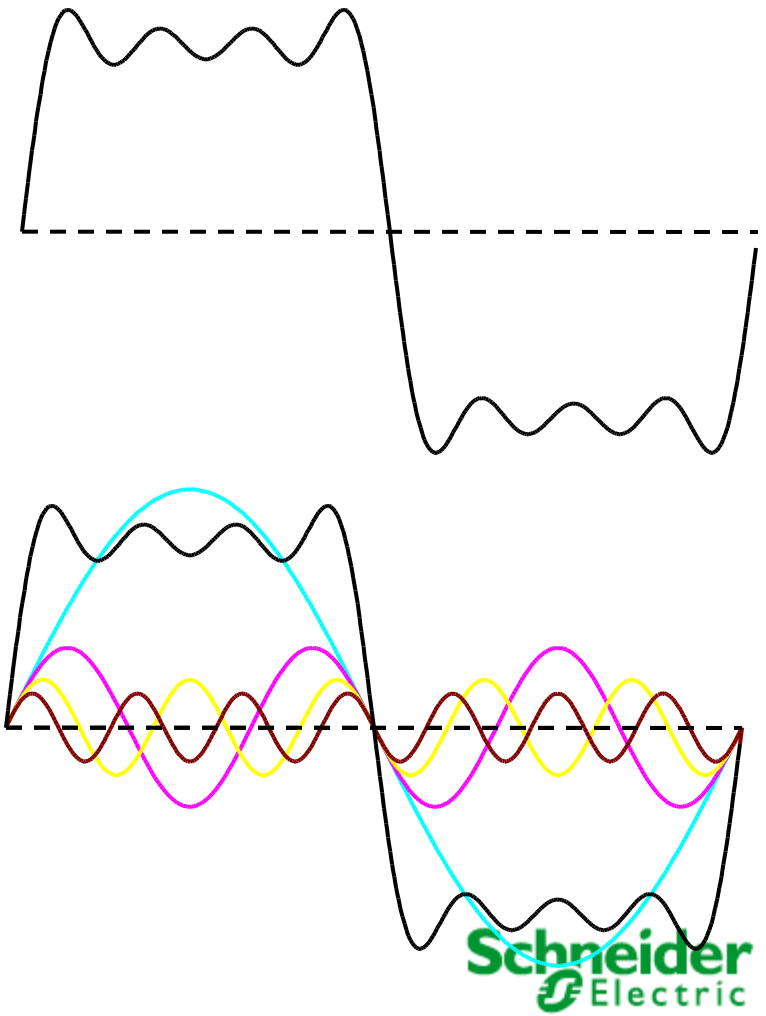
Distortion: what is it ?

- A **linear** waveform is a *sinusoidal* and *periodic* waveform (current or voltage)
- A **non-linear** (or distorted) waveform is any periodic waveform (current or voltage) which is non-sinusoidal



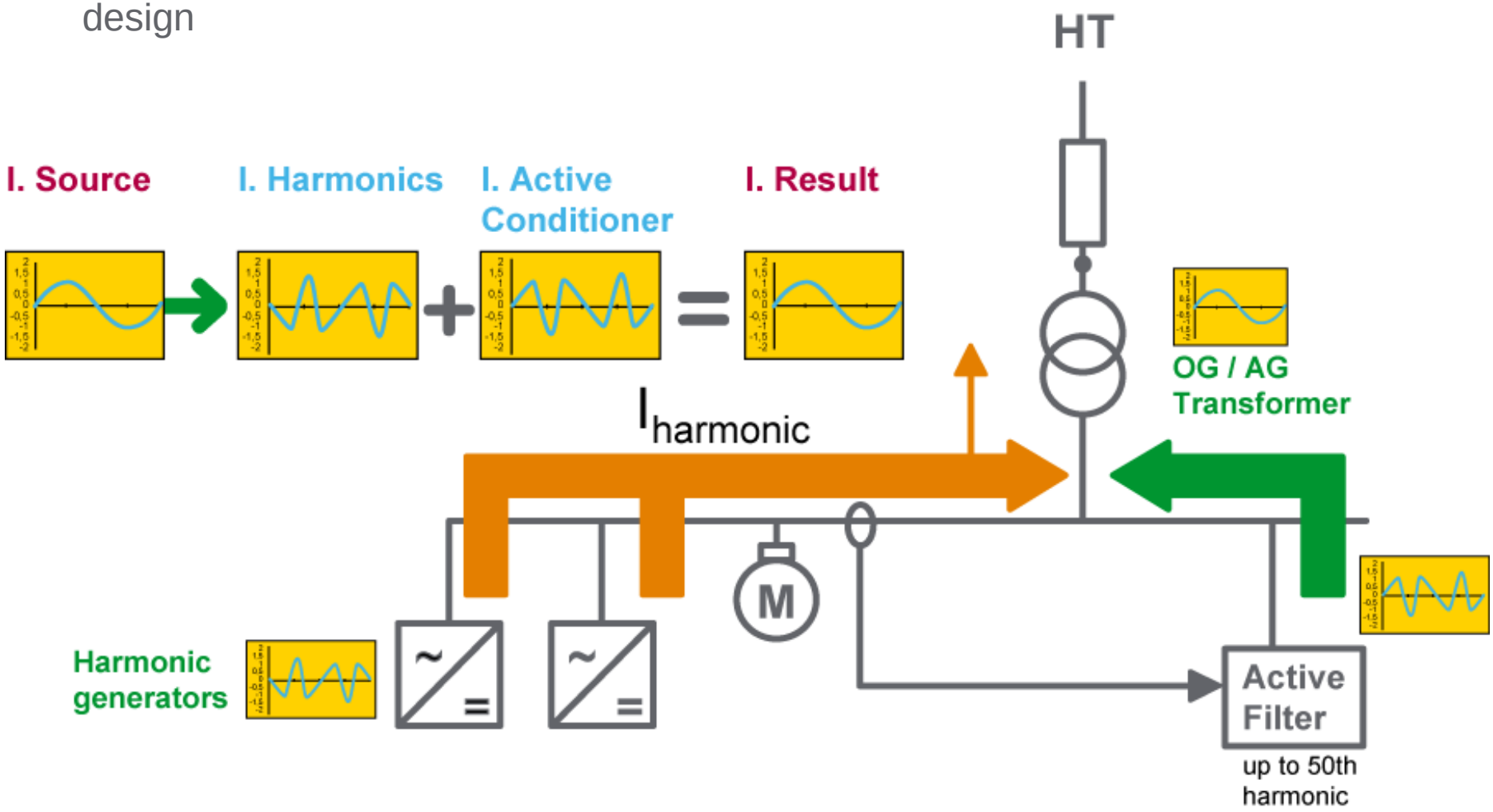
Distortion and Harmonics

- A distorted waveform can be represented as the sum of its Harmonics



Active Harmonic Filtering

- Some harmonics are a source of disturbances and have to be taken into account in electrical network design



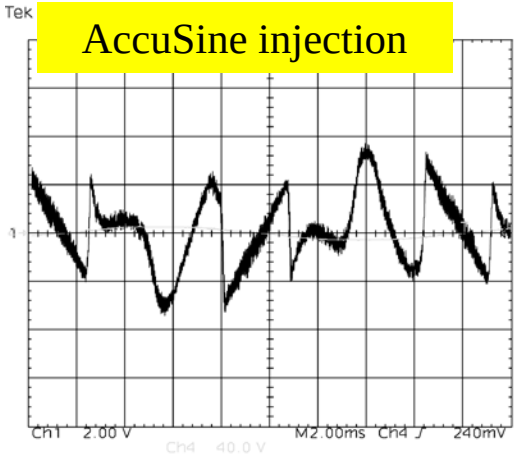
AccuSine® PCS

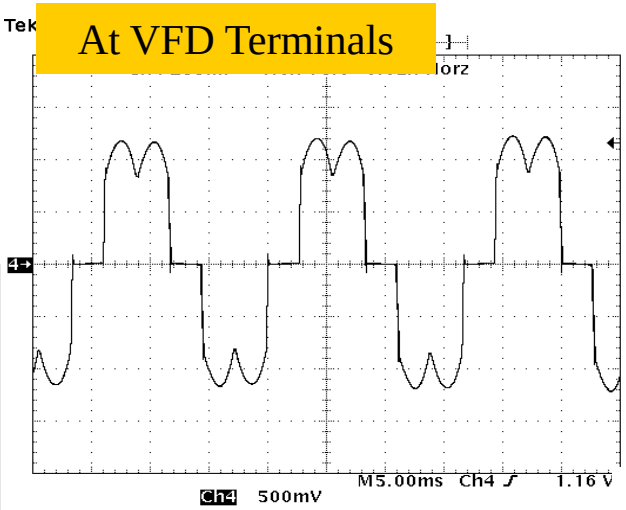
- Expanded Product Line
  - 208 – 480 VAC, +10%, -15% @ 50 or 60 Hz
  - 600 VAC (includes autotransformer)
  - 690 VAC (includes autotransformer)
  - Use customized transformers for higher voltages (to 15 kV)

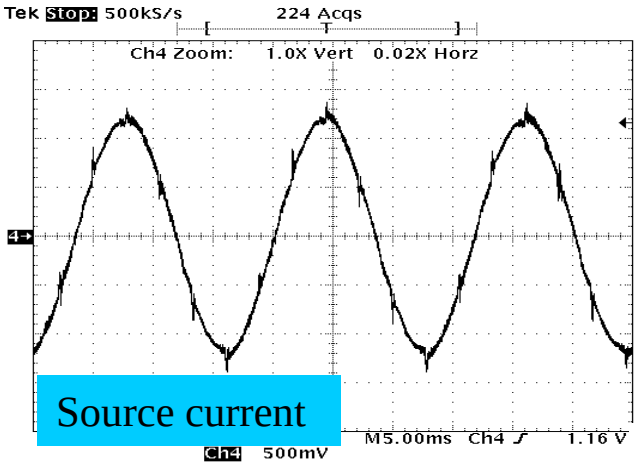
- cULus 508 or UL/CSA approved – 208-480V & 600V
- CE (EMC) - 400/480V, 600V, & 690V
- UL Type 1 & 12; IP30 & IP54 enclosures

AccuSine® PCS

Harmonic Performance

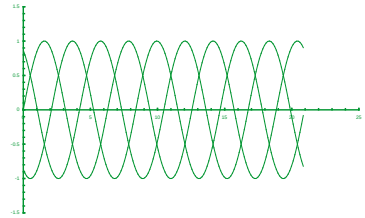




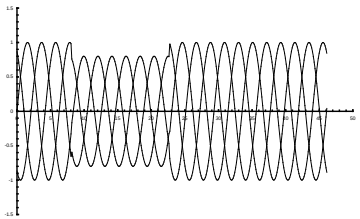


Order	AS off % I fund	AS on % I fund
Fund	100.000%	100.000%
3	0.038%	0.478%
5	31.660%	0.674%
7	11.480%	0.679%
9	0.435%	0.297%
11	7.068%	0.710%
13	4.267%	0.521%
15	0.367%	0.052%
17	3.438%	0.464%
19	2.904%	0.639%
21	0.284%	0.263%
23	2.042%	0.409%
25	2.177%	0.489%
27	0.293%	0.170%
29	1.238%	0.397%
31	1.740%	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%

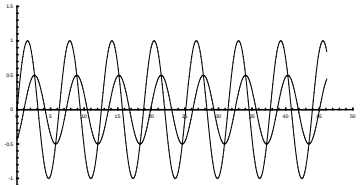
The ideal voltage supply does not exist



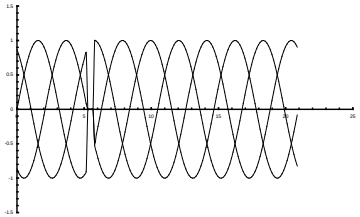
3-phase balanced



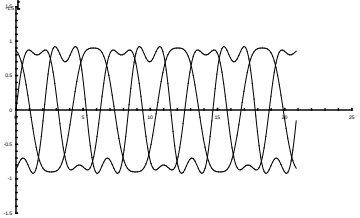
Sags/swells
Overvoltage



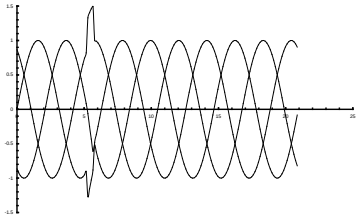
Power Factor



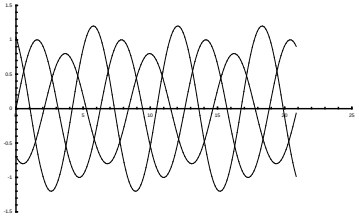
notches



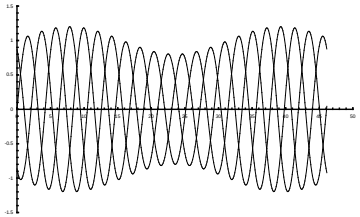
Harmonics



Spikes



Phase unbalanced

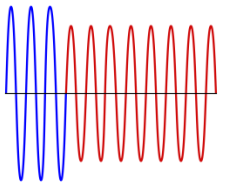


Flicker

Voltage Problems – Basics

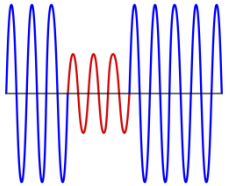
Chronic Voltage Regulation issues

- Voltage outside ±10% for > 60 seconds



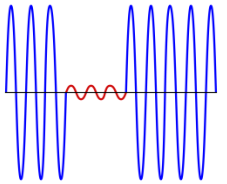
Voltage Sag

- Voltage < 90% for ½ cycle to 1 minute



Interruption

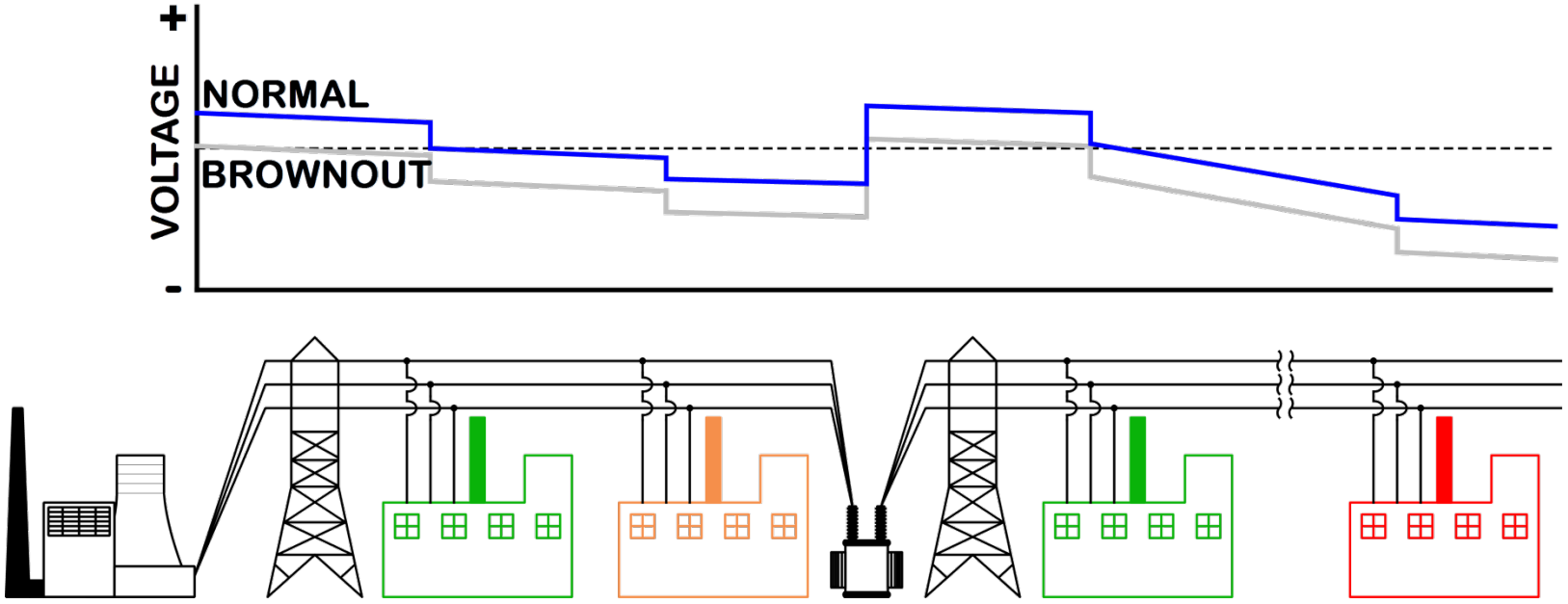
- Voltage < 10% for >3 cycles



95% of Voltage Quality Problems

Schneider Electric

Chronic Voltage Problems



Brownout – intentional reduction in grid voltage

External: Line Drops & Brownouts

Sure-Volt ™ - Voltage regulator

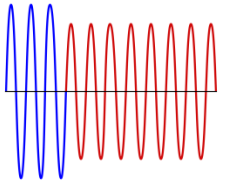
- **The standard Sure-Volt™:**
  - Microprocessor controlled tap-switching
  - Input voltage range: **+10 to -25%**
  - Output regulation: **±3%**
  - Response time: 1 cycle typical
  - Overload capacity: 1000% for 1 second
  - No load or power factor limitations
  - Independently regulated, shielded, isolated output
  - Fan-free and maintenance-free
  - Single or three phase
  - 5 to 2,000 kVA
  - 50 or 60 Hz
  - Any input or output voltages up to 600v

Schneider Electric

Voltage Problems – Basics

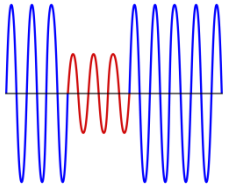
Chronic Voltage Problems

- Voltage outside ±10% for > 60 seconds



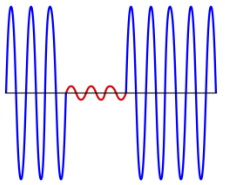
Voltage Sag

- Voltage < 90% for ½ cycle to 1 minute



Interruption

- Voltage < 10% for >3 cycles



95% of Voltage Quality Problems

Schneider Electric

Sag Fighter™ - Voltage regulator

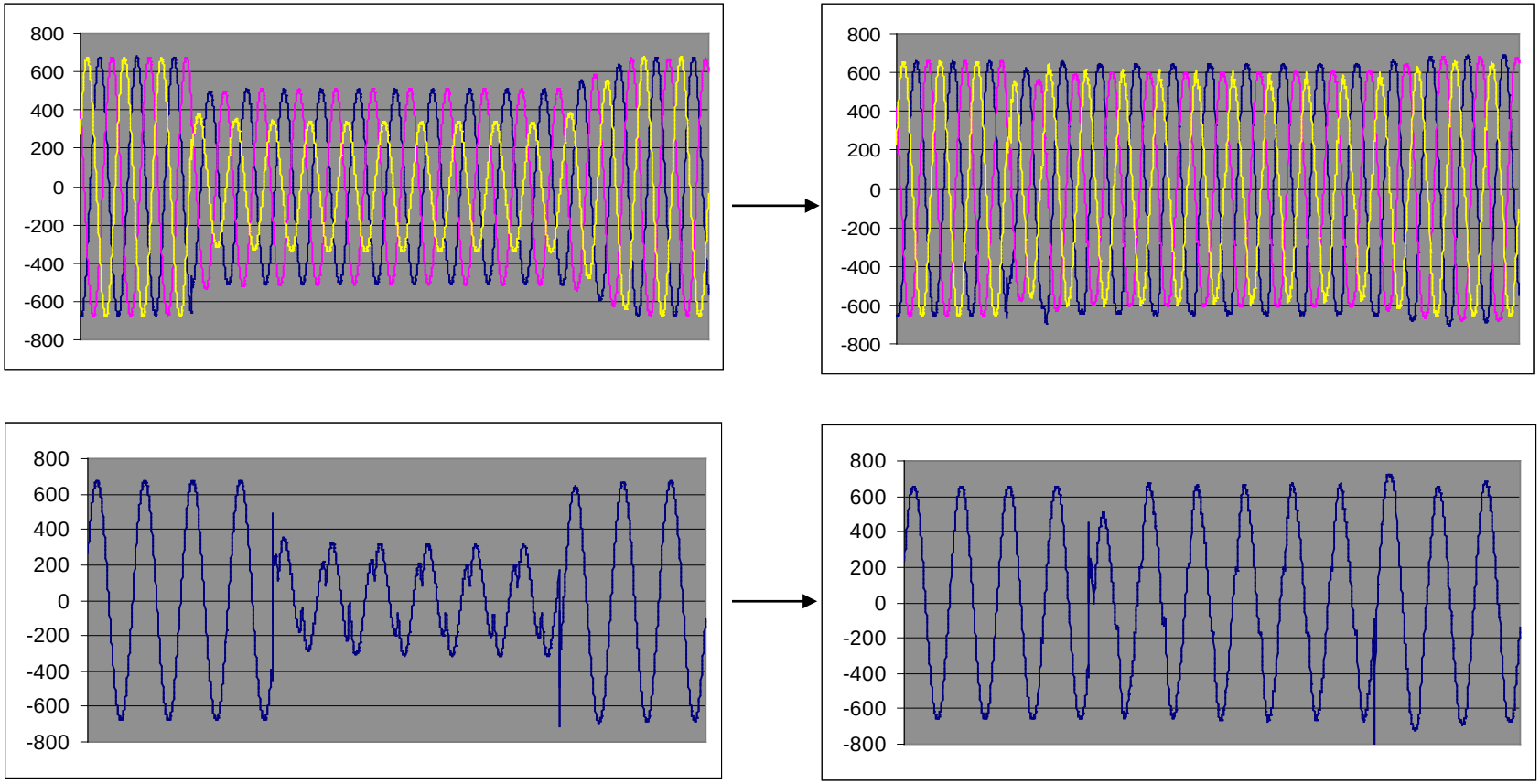
- **The standard Sag Fighter™:**
  - Inverter-based, voltage injection design
  - Corrects voltage sags back to >95% nominal voltage
  - For sags down to **30% remaining voltage for 1 or 2 phase sags**
  - For sags down to **60% remaining voltage for 3 phase sags**
  - 2ms response time
  - Provides SEMI-F47 compliant protection
  - Correction independent of load or load pf, sag depth or duration
  - Corrects phase shifting during sag event

What are the solutions

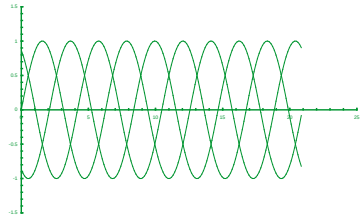
Electronic Sag Fighter Performance

Input

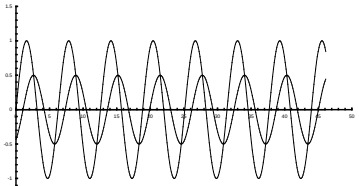
Output



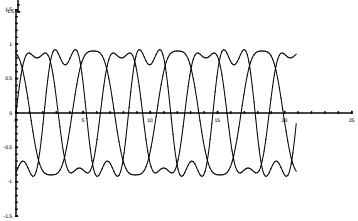
The ideal voltage supply does not exist



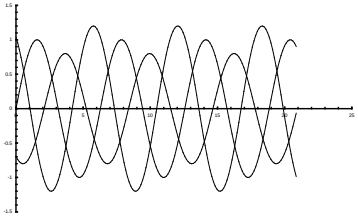
3-phase balanced



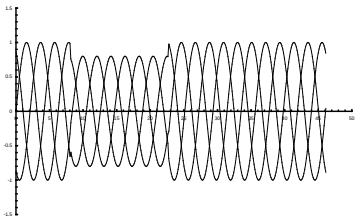
Power Factor



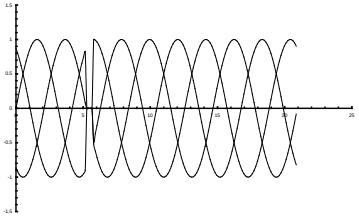
Harmonics



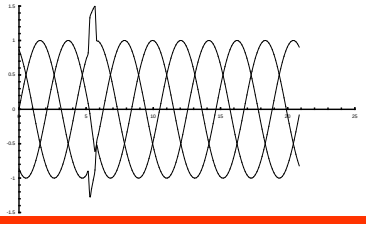
Phase unbalanced



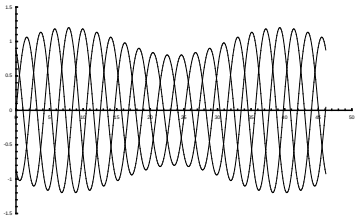
Sags/swells
Overvoltage



notches

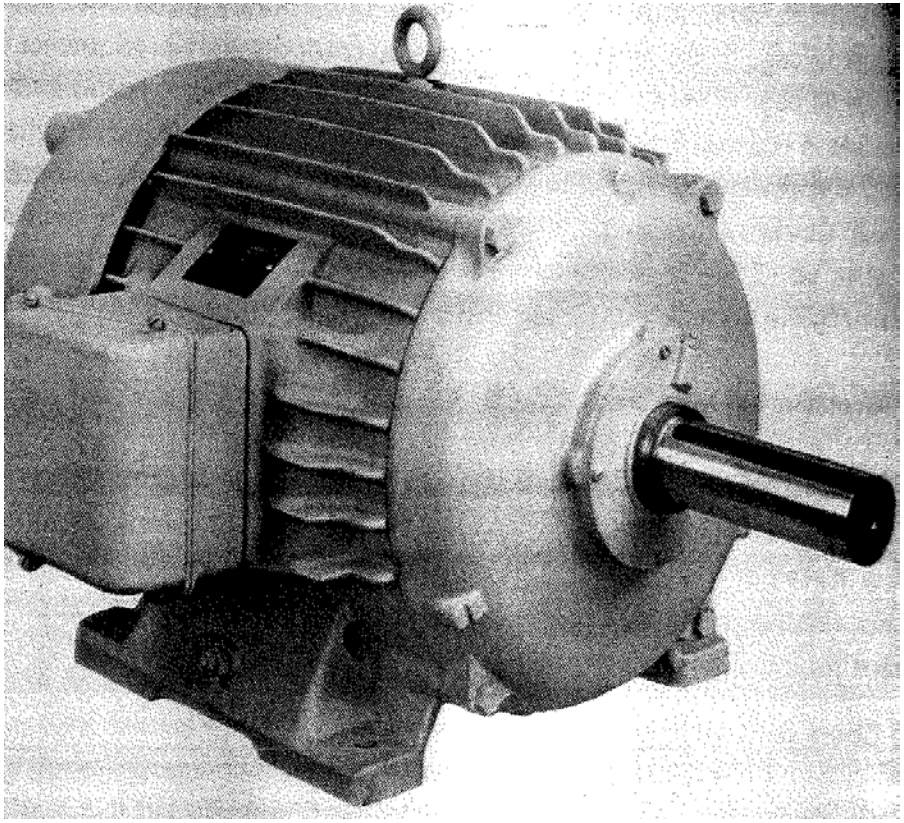


Spikes



Flicker

Welding or Large Motor Start Up



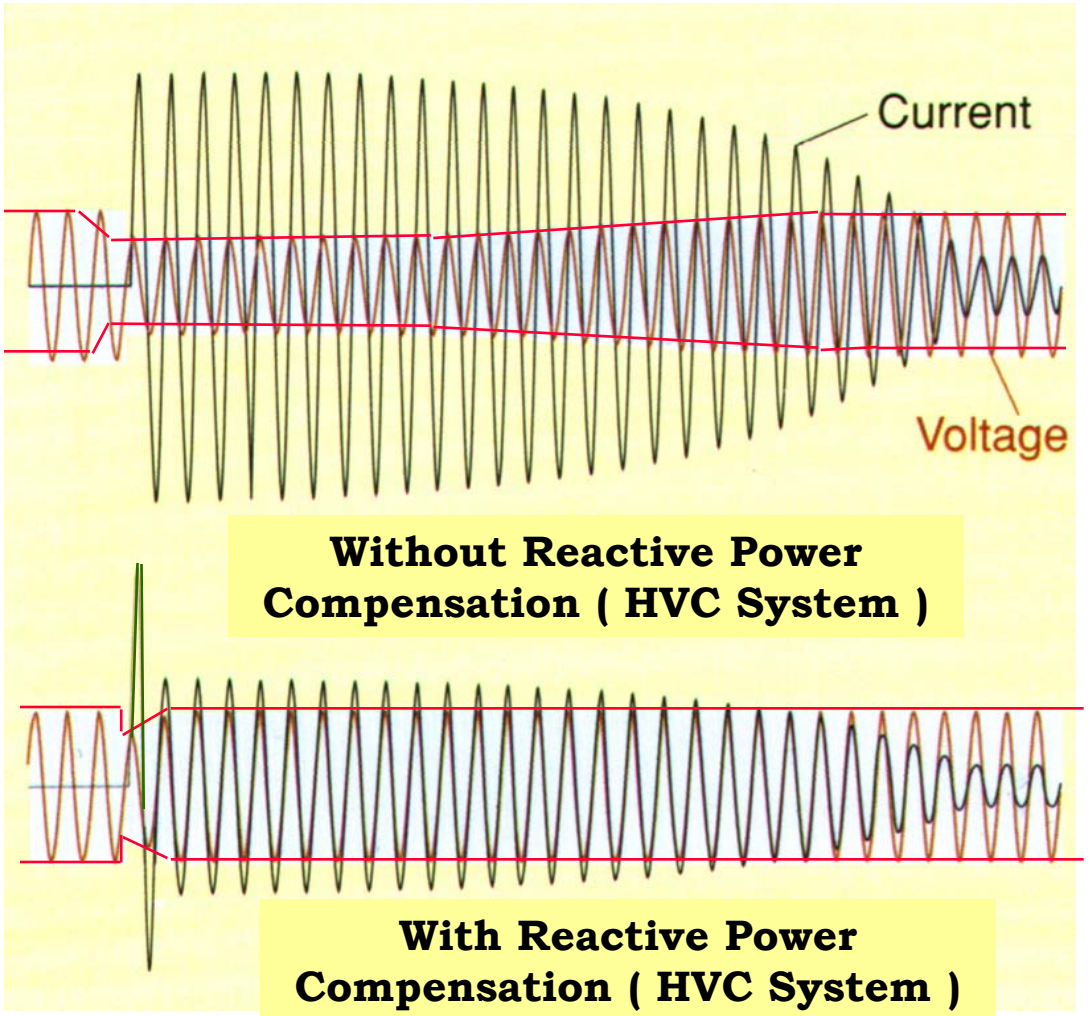
Hybrid Var Compensator (HVC)

- Combination of passive & active technologies

+

Schneider Electric

Motor Start Waveforms



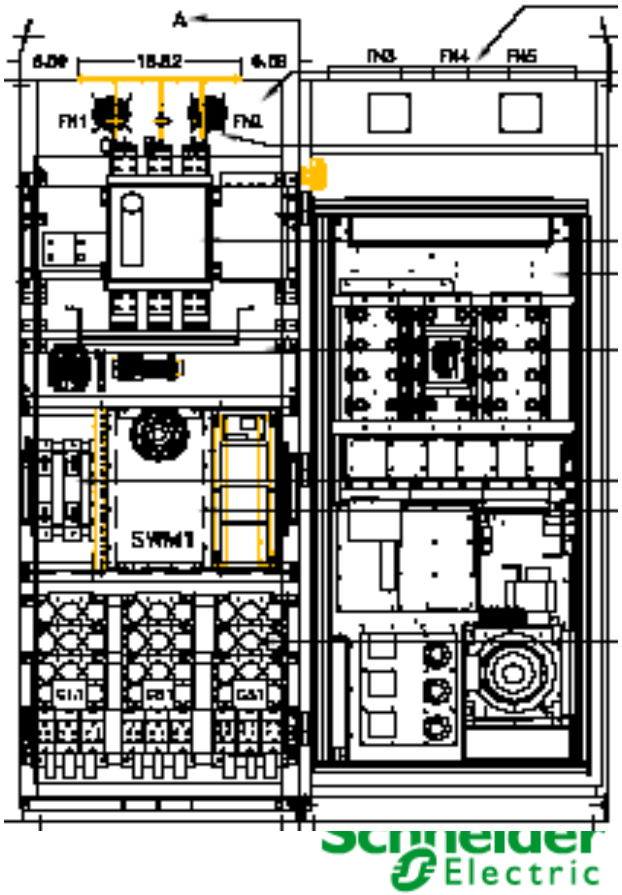
(The elimination of high current inrush and voltage sags during motor startup cannot be successfully achieved by switching a capacitor with the motor starter.)

The dominant component of motor startup current is reactive.

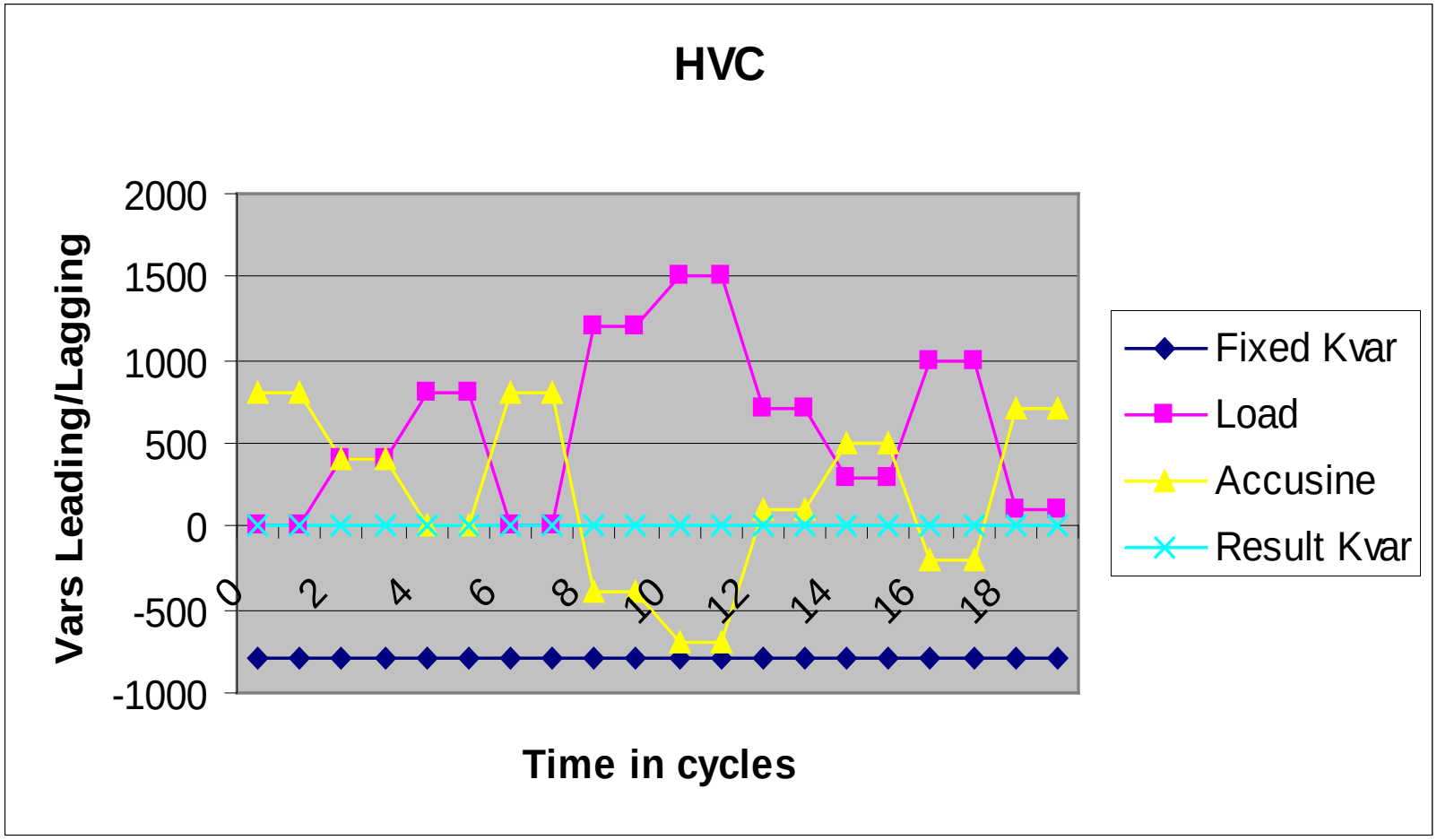
Compensation substantially decreases reactive current and eliminates voltage sags.

Hybrid Var Compensator (HVC)

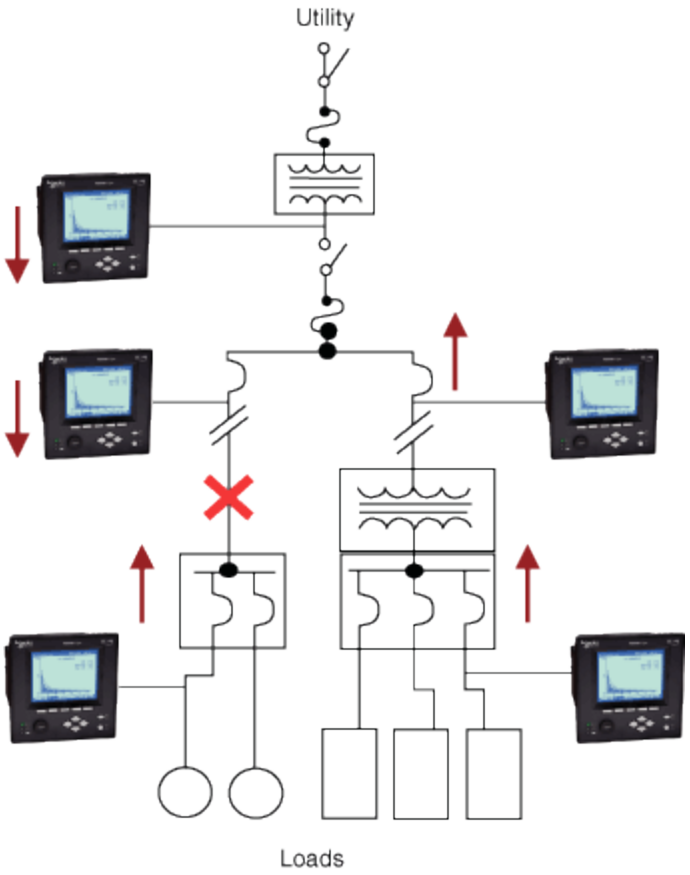
- Available in Low and Medium Voltage
- High Speed Response
- Infinite Variability
- Full Duration
- Unity Power Factor



Hybrid Var Compensator (HVC)



Disturbance Direction Detection



- Determine the location of a voltage disturbance relative to the meter.
- Analyzing disturbance direction detection information from multiple meters in a power monitoring system enables the location of the cause of the disturbance to be determined more quickly and accurately.
- Disturbance Direction Detection is standard in ION7550 and ION7650 meters.

EN 50160 (European Norm 50160)

- This European standard has been accepted by many countries around the world for transmission and distribution systems.
- It defines acceptable levels of power quality phenomena, including:
  - Power Frequency
  - Flicker
  - Supply voltage dips
  - Short & long interruptions
  - Temporary over voltage
  - Supply voltage magnitude
  - Supply voltage unbalance
  - Harmonic voltage
  - Inter-harmonic voltage
  - Mains signaling voltage
- It uses a statistical approach to see if the system meets compliance
  - For example, power frequency the system value must be within ±0.5 Hz for 95% of the time, and within +2 Hz to -3 Hz for 100% of the time
- EN 50160 data reporting is available on the ION7650 and ION8650.

Schneider Electric

Make the most of your energy™

Thank you

Schneider Electric