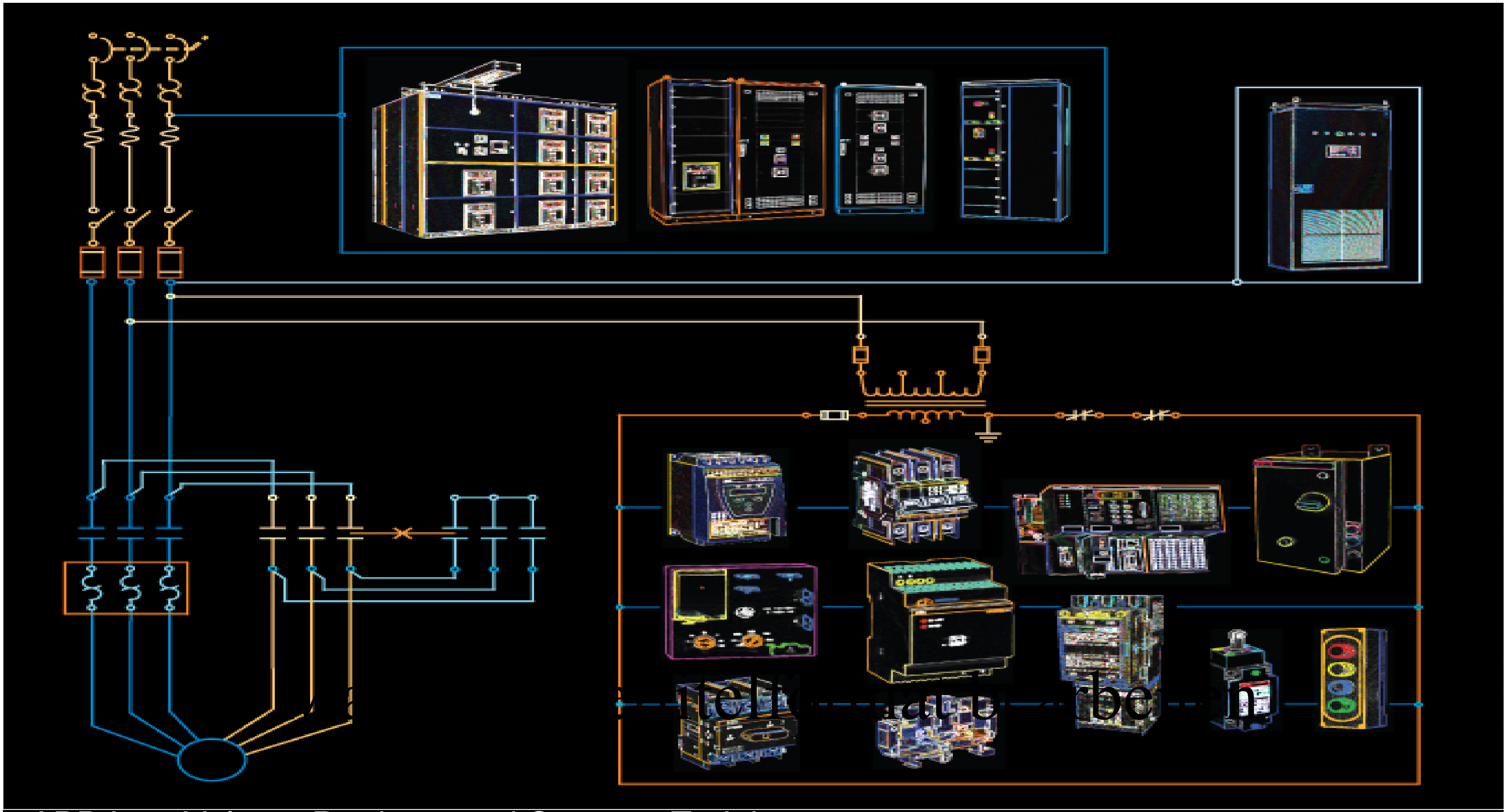

ABB Low Voltage Products and Systems Training

Poor Power Quality

What Impact Does it Have on You?

Poor Power Quality
What Impact Does it Have on You?

Any event related to the electrical network that results in LOST MONEY…

- Utility regulations and power factor penalties
- Larger than necessary power distribution network
- Power supply failures – Breakers tripping, fuses blowing
- Equipment failure, malfunction and lifetime reduction - Equipment overheating (transformers, motors, …)
- Damage to sensitive equipment (PCs, UPS-systems, Drives)
- Capacitor problems
- Electronic communication interference

Poor Power Quality
What Impact Does it Have on You?

Key elements of poor Low Power Quality

Power Factor

Harmonics

Load imbalance

Down-time and high operating costs!

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Poor Power Quality
What Impact Does it Have on You?

Poor Power Quality Costs

Sector	Financial loss per incident
Semi-conductors production(*)	3.800.000 €
Financial trade(*)	6.000.000 € per hour
Computer center(*)	750.000 €
Telecommunication(*)	30.000 € per minute
Steel industry(*)	350.000 €
Glass industry(*)	250.000 €
Offshore platforms	250000 € per day
Dredging/land reclamation	50000 – 250000 € per day

- $5,320,000
- $8,400,000 per hr
- $1,050,000
- $42,000 per min
- $490,000
- $350,000
- $350,000 per day
- $70K - $350k per day

(*) European Copper Institute 2002

Poor Power Quality
What Impact Does it Have on You?

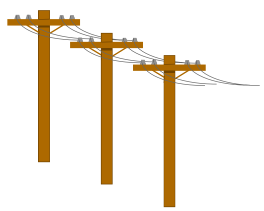
PRESENTATION TOPICS:

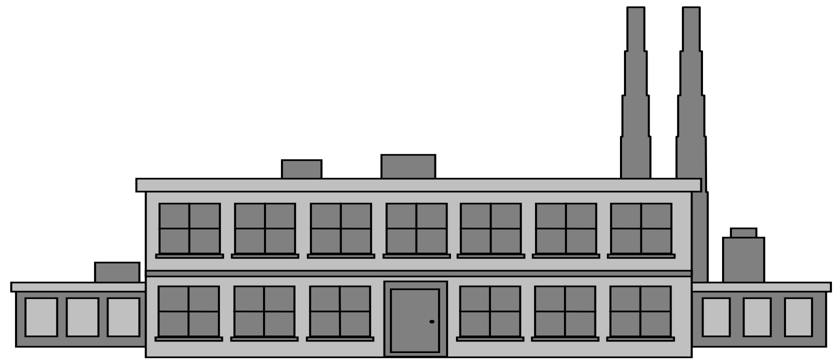
- Power Factor Correction & Benefits
- TVA Power Factor Rate Structures & Case Studies (PF improvement, monetary savings example)
- Harmonics
- Power Quality Problems caused by Harmonics
- Power Factor Correction and Harmonic Filtering Solutions
- PQ Improvement Equipment Application Considerations and how to design for a safe and durable installation
- The Future in Power Quality Improvement, Active Filters
- Questions and Answers

Poor Power Quality

What Impact Does it Have on You?

WHAT IS POWER FACTOR ?





- Power factor is the measurement of how effectively electrical power is being used.
- The higher the power factor the more efficient the plant. ….and all the way back to the generator!

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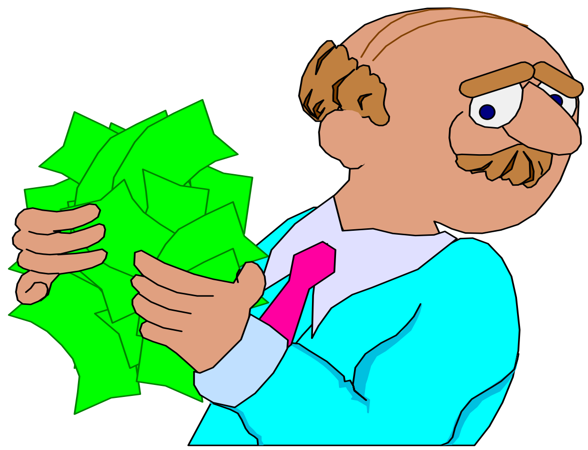
Poor Power Quality
What Impact Does it Have on You?

WHY WORRY ABOUT POWER FACTOR ?



- A bad power factor costs money!!!

Poor Power Quality
What Impact Does it Have on You?

WHAT CAUSES POOR POWER FACTOR?

- **Induction Devices (such as motors)**
- **Transformers (which require magnetizing current)**
- **Lighting Ballasts**

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Poor Power Quality

What Impact Does it Have on You?

OK - BUT WHAT IS POWER FACTOR ?

Poor Power Quality

What Impact Does it Have on You?

POWER FACTOR TERMINOLOGY

VAR – **volt ampere reactive**

Measurement of reactive power (KVAR)

Inductive loads require magnetizing current to operate (motors)

Sometimes referred to as <u>Imaginary</u> or <u>Non-Working Power</u>

KW – **kilowatts**

Measurement of energy

Sometimes referred to a <u>Real Power</u> or <u>Active Power</u>

KVA – **kilovolt-ampere**

Measurement of total power draw

Sometimes referred to as <u>Apparent Power</u> or <u>Total Power</u>

POWER FACTOR

PF = KW / KVA

Measurement of how efficiently power is being delivered from generation to the load

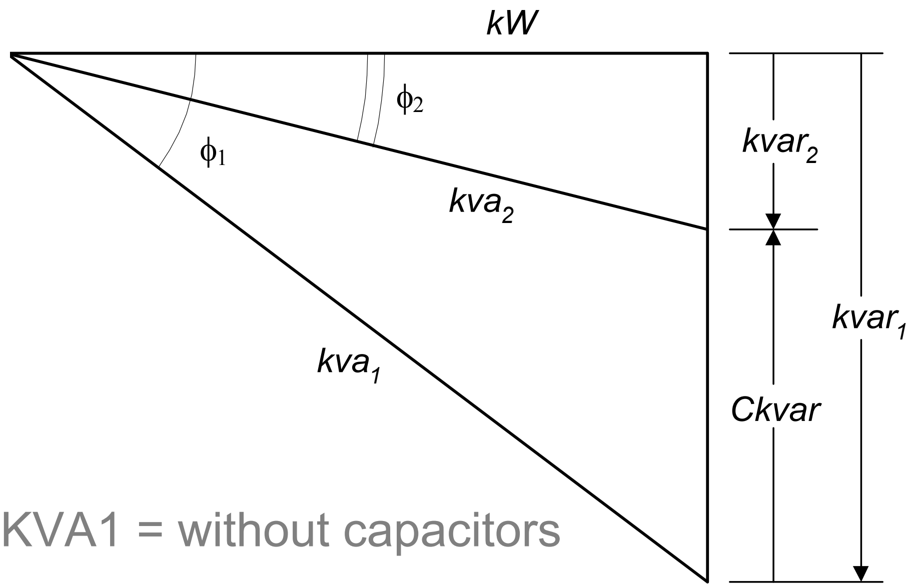
Low power factor – VAR's travel from generator to load

High power factor – VAR's supplied near the load

Poor Power Quality

What Impact Does it Have on You?

INTRODUCING THE POWER FACTOR TRIANGLE



- kVA: Total Power
- kW: Working Power
- kVAR: Reactive Power needed to generate magnetic fields
- Power Factor: The relationship of kW and kVA consumed
- Cosine of angle shown as a % or decimal expression: **PF = kW / kVA**

- KVA1 = without capacitors
- KVA2 = with capacitors
- KVA2 < KVA1

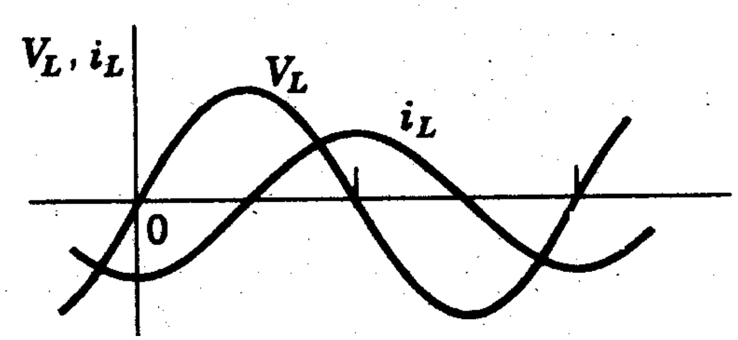
Action Taken:
- Addition of Capacitors

Impact:
- Less KVA to support the same load
- Capacitors supply portion of reactive power
- Power Factor is improved

Poor Power Quality

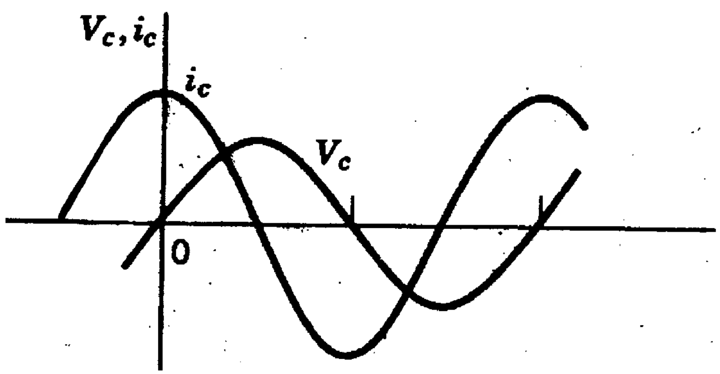
What Impact Does it Have on You?

LAGGING & LEADING POWER FACTOR



LAGGING – Current Lags Voltage

Unity P.F. – both are in synch



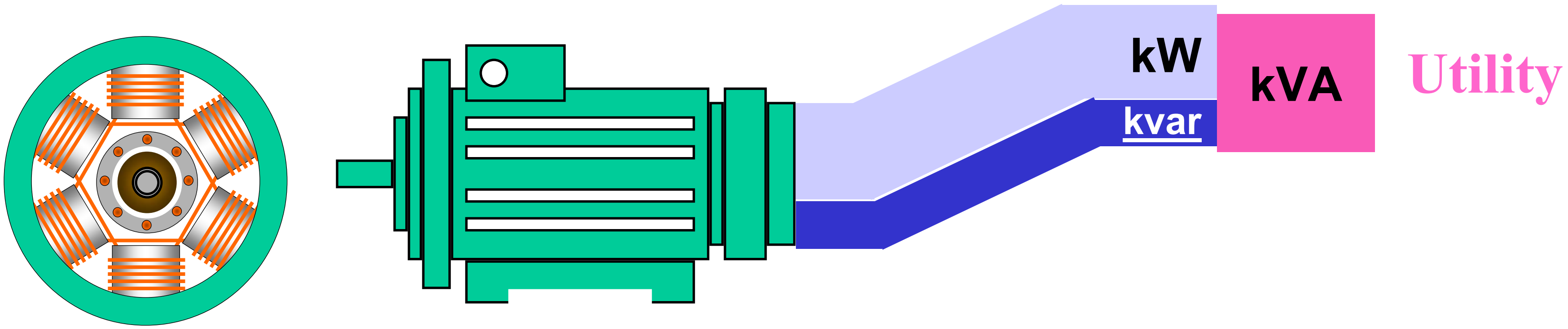
- **LEADING – Current Leads Voltage**

  VARS flow back into system, causing protective relays to operate and drop service – NOT GOOD

Poor Power Quality
What Impact Does it Have on You?

- Active power (kW)
☞ **performs the work (useful power)**

- Reactive power (kvar)
☞ **sustains electromagnetic field (non useful power)**



- Apparent power (kVA)
☞ **total power consumed**

- Power Factor = (kW / kVA)
measure of how effeciently power is used

Poor Power Quality
What Impact Does it Have on You?

HOW CAN WE CORRECT POOR POWER FACTOR ?

- Increase generation capacity ($60M / 100 MW Plant)
- Build new transmission lines ($1M/mile)
- Build new distribution lines ($100K/mile)
- Re-conductor existing lines ($100K/mile)
- Increase transformer size
- Install voltage regulators

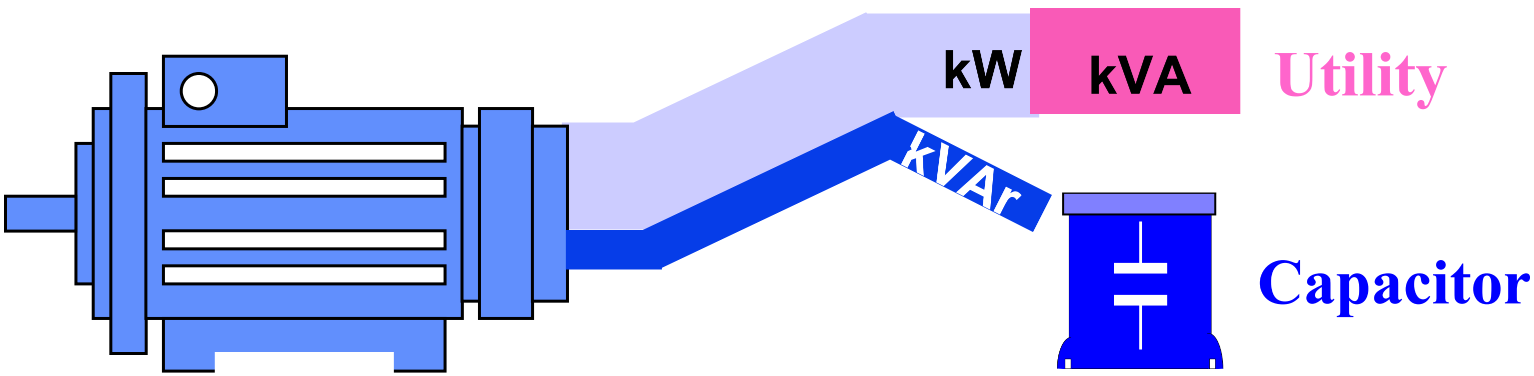
OR:

- **INSTALL CAPACITORS (MV = $10-20 / KVAr; LV = $40-50 / KVAr) !**
- **Capacitors are most practical solution**

Poor Power Quality

What Impact Does it Have on You?

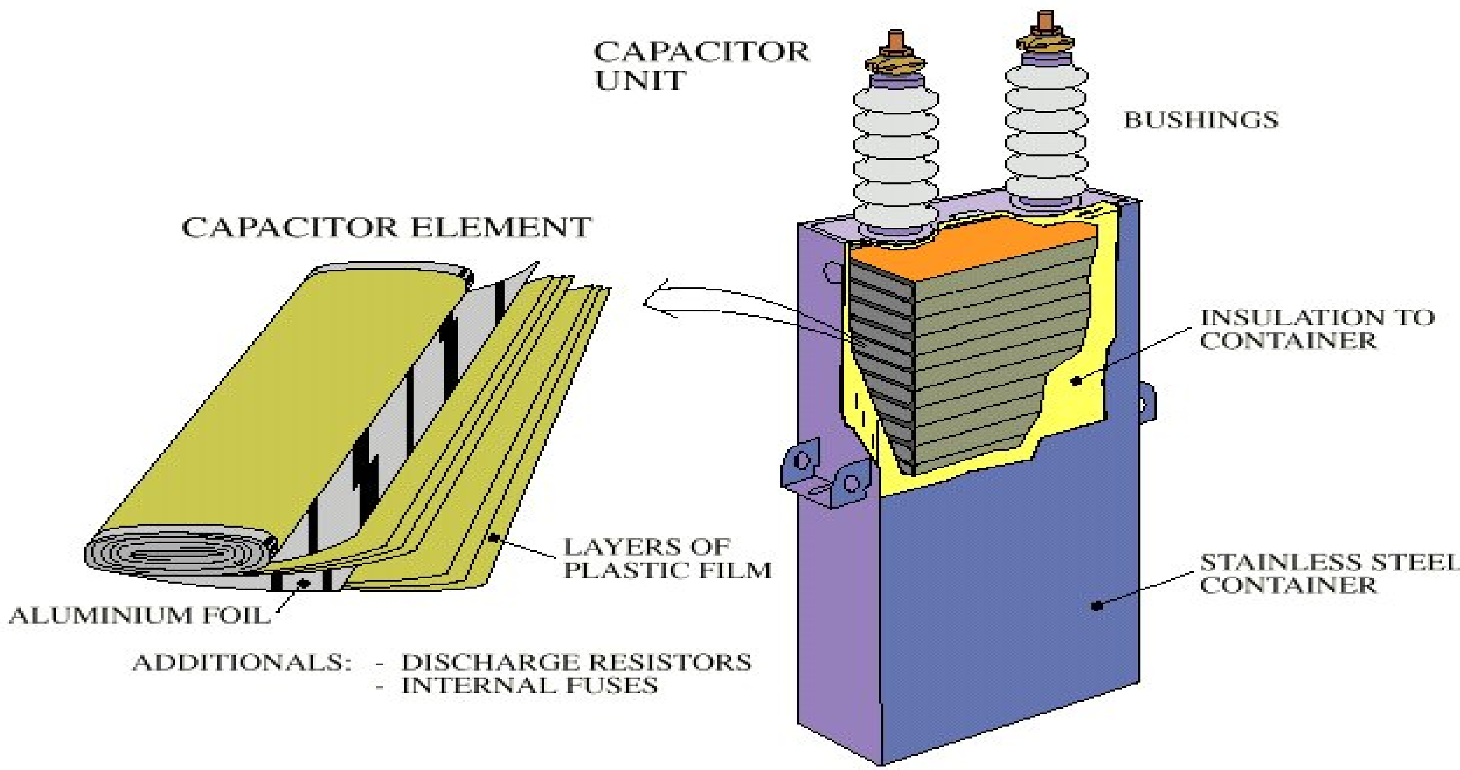
HOW CAN WE CORRECT POWER FACTOR?



A capacitor connected locally at motor or distribution system will reduce KVA consumed from Utility

Poor Power Quality
What Impact Does it Have on You?

WHAT IS A CAPACITOR ?



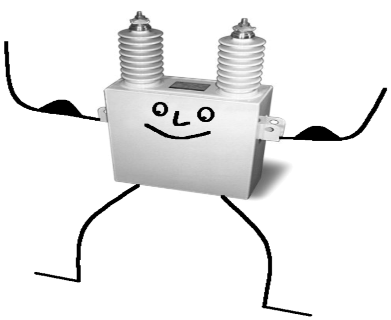
Poor Power Quality
What Impact Does it Have on You?

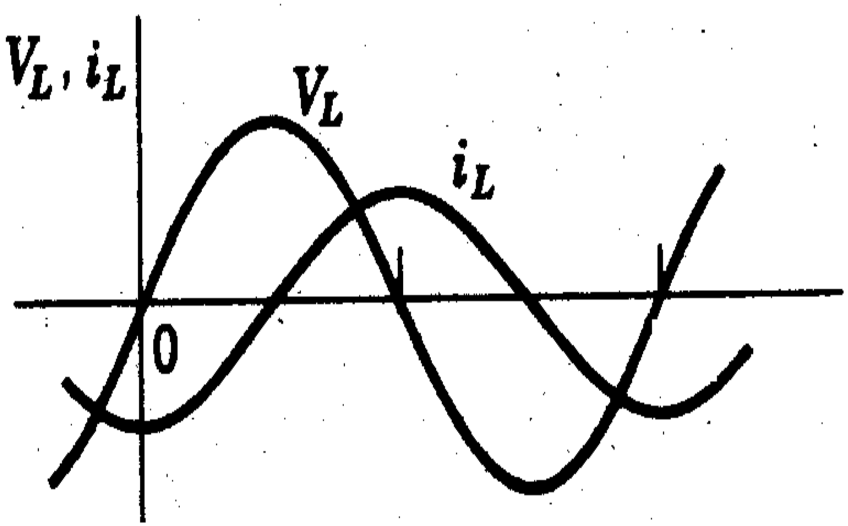
WHAT DOES A CAPACITOR DO ?

PROVIDES
REACTIVE POWER
(KVAR)
TO THE
POWER SYSTEM!!!

Poor Power Quality
What Impact Does it Have on You?

HOW DOES A CAPACITOR DO THAT ?

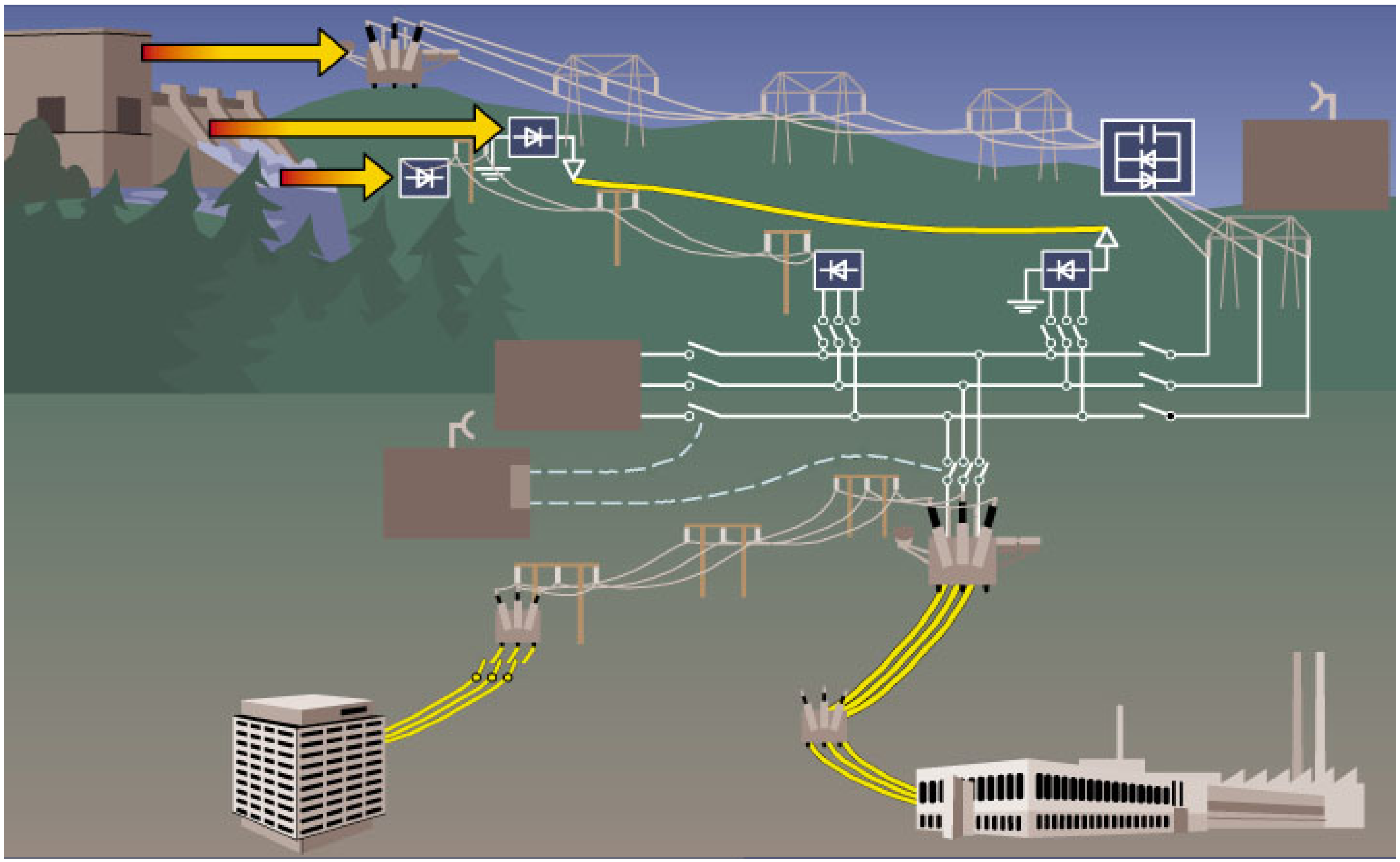




- **STATIC DEVICE – NO MOVING PARTS**
- **TAKES FROM SYSTEM ON 1ST HALF-CYCLE**
- **RETURNS TO SYSTEM ON 2ND HALF-CYCLE**

Poor Power Quality
What Impact Does it Have on You?

POWER SYSTEMS REQUIRE REACTIVE POWER



Poor Power Quality
What Impact Does it Have on You?

WHY CORRECT POWER FACTOR ?

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Poor Power Quality
What Impact Does it Have on You?

GOOD QUESTION – HERE'S WHY

- When low power factor is not corrected, the power utilities need to provide reactive power
  - Larger equipment (ie. poles and wires) required to supply power
  - System capacity problems lead to 'brown-outs'

- Power utility's operating costs are higher, OFTEN resulting in power factor penalties to customers
  - Maximum Demand charges

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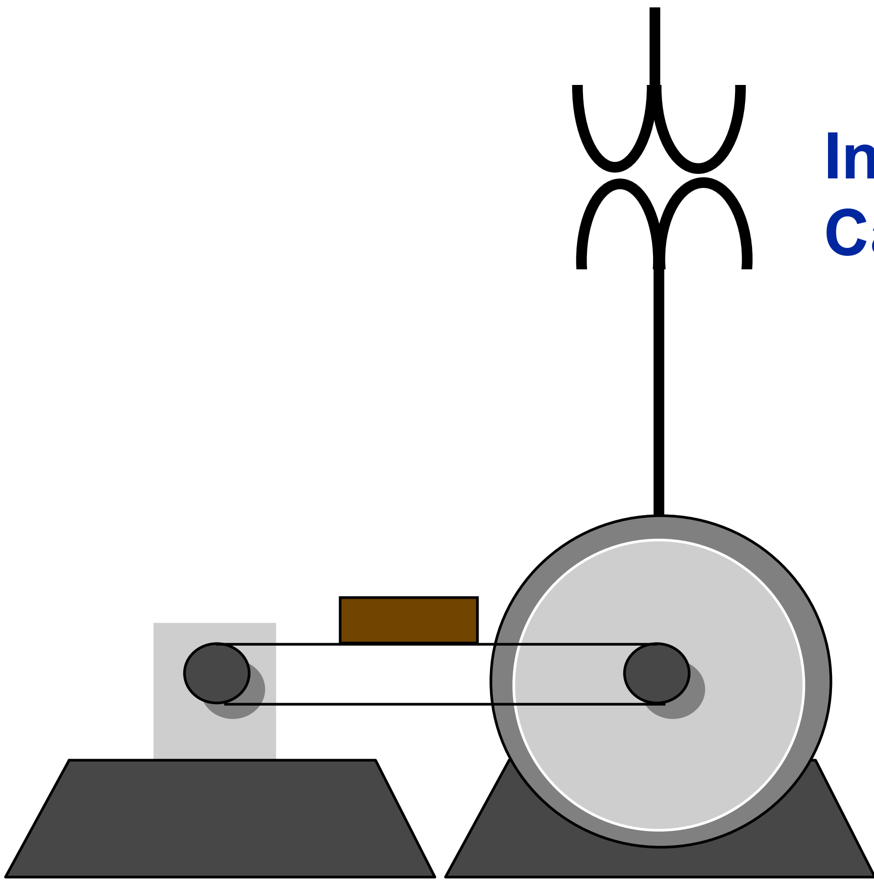
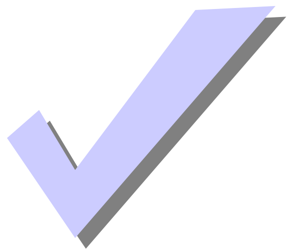
Poor Power Quality

What Impact Does it Have on You?

WHY CORRECT POWER FACTOR?



Increase Network Capacity



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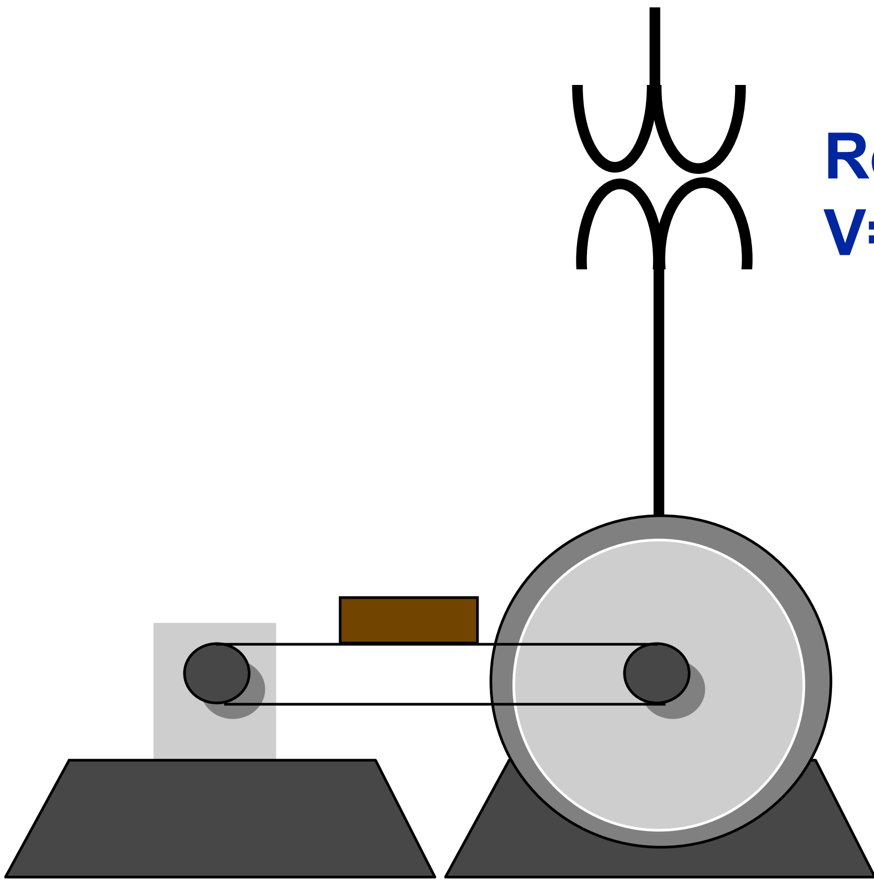
Poor Power Quality

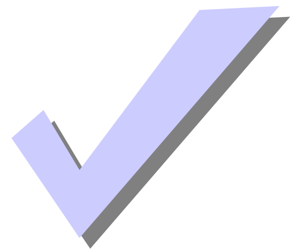
What Impact Does it Have on You?

WHY CORRECT POWER FACTOR?



Reduce Voltage Drop

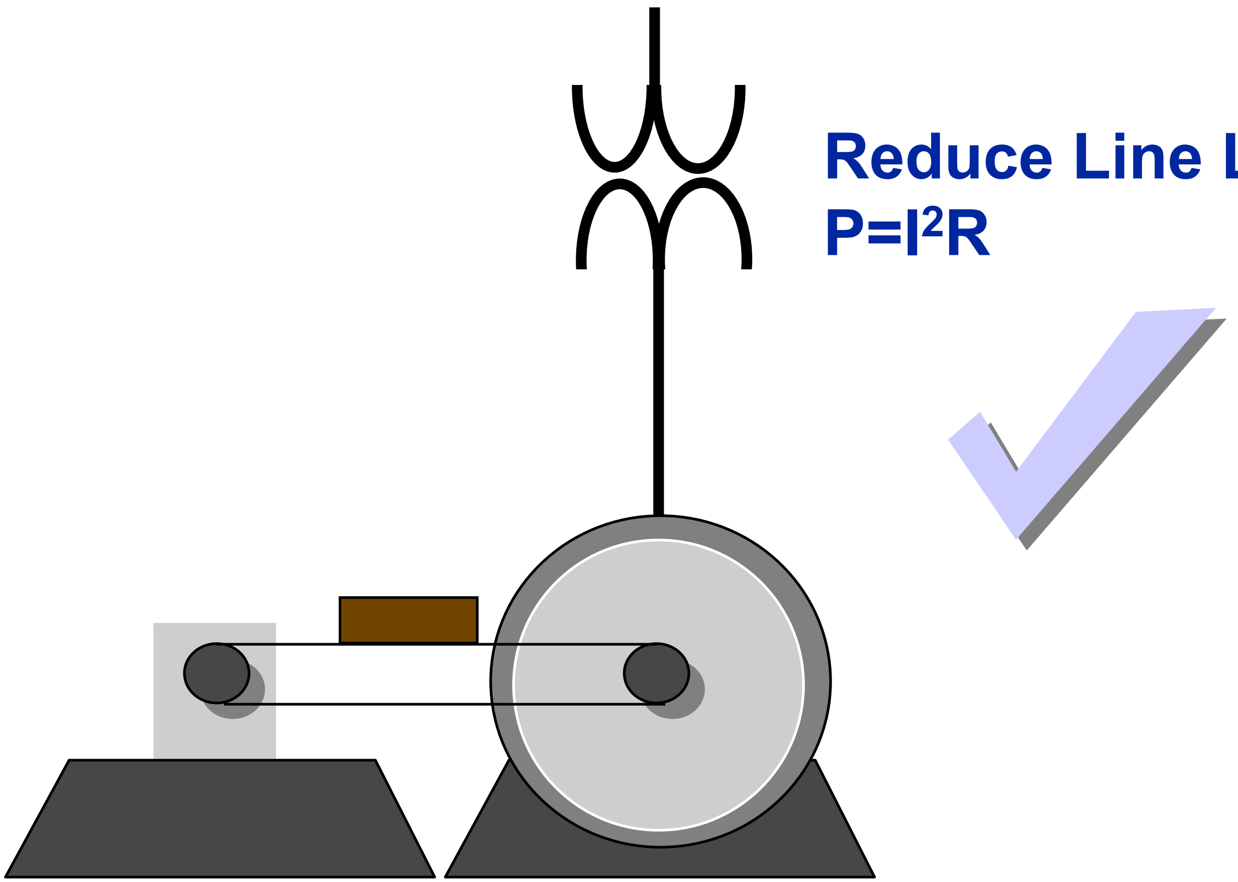
V=IR



Poor Power Quality

What Impact Does it Have on You?

WHY CORRECT POWER FACTOR?



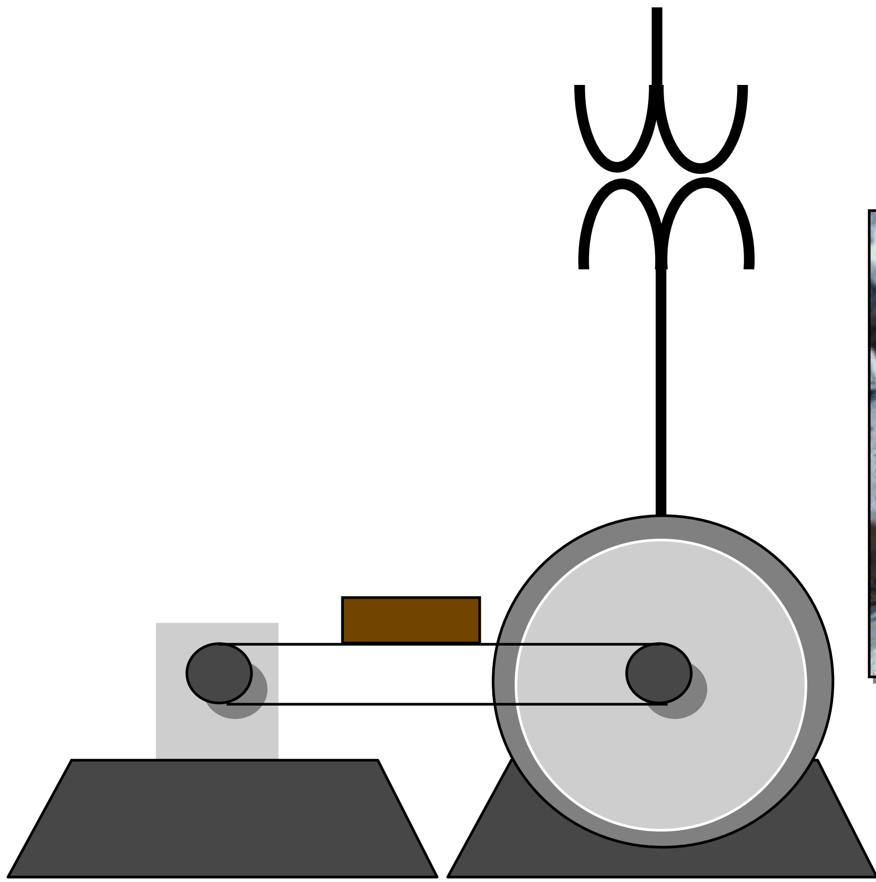
Reduce Line Loss

$P=I^2R$

Poor Power Quality

What Impact Does it Have on You?

WHY CORRECT POWER FACTOR?



Save Money!

Poor Power Quality
What Impact Does it Have on You?

PF CORRECTION - UTILITY BENEFITS

- Reduce power generation (kVA)
- Increase supply network capacity
- Lower operating and maintenance cost
- Reduce carbon emissions (environment)

Poor Power Quality
What Impact Does it Have on You?

PF CORRECTION – END USER BENEFITS

- Lower utility bills (lower operating costs)
- If Low Voltage capacitors installed – customer can increase their own network capacity and reduce their energy waste (heat losses)
- Reduce carbon emissions (environment)

Poor Power Quality
What Impact Does it Have on You?

POWER FACTOR CORRECTION METHODS:

- Individual Capacitors at the Motor
- Fixed Capacitors on the Network
- Automatic Capacitor Banks (The Trend Today)

Poor Power Quality
What Impact Does it Have on You?

ADVANTAGES OF MEDIUM AND HIGH VOLTAGE CAPACITORS:

- Reduces loading of Medium and High Voltage distribution system.
- Reduces Medium Voltage and High Voltage impedance heat losses.
- Lower cost than Low Voltage Capacitor Systems.

Poor Power Quality
What Impact Does it Have on You?

ADVANTAGES OF LOW VOLTAGE CAPACITORS:

- Reduces loading of user's feeding transformer.
- Reduces Low Voltage, Medium Voltage and High Voltage impedance heat losses.
- Potential lower installation cost than Medium and High Voltage capacitors as Low Voltage capacitors can be installed by customer's in-house qualified personnel.

Poor Power Quality
What Impact Does it Have on You?

TVA Rate Structure:

- Gerald to provide

Poor Power Quality

What Impact Does it Have on You?

PF Correction Savings Example(s):

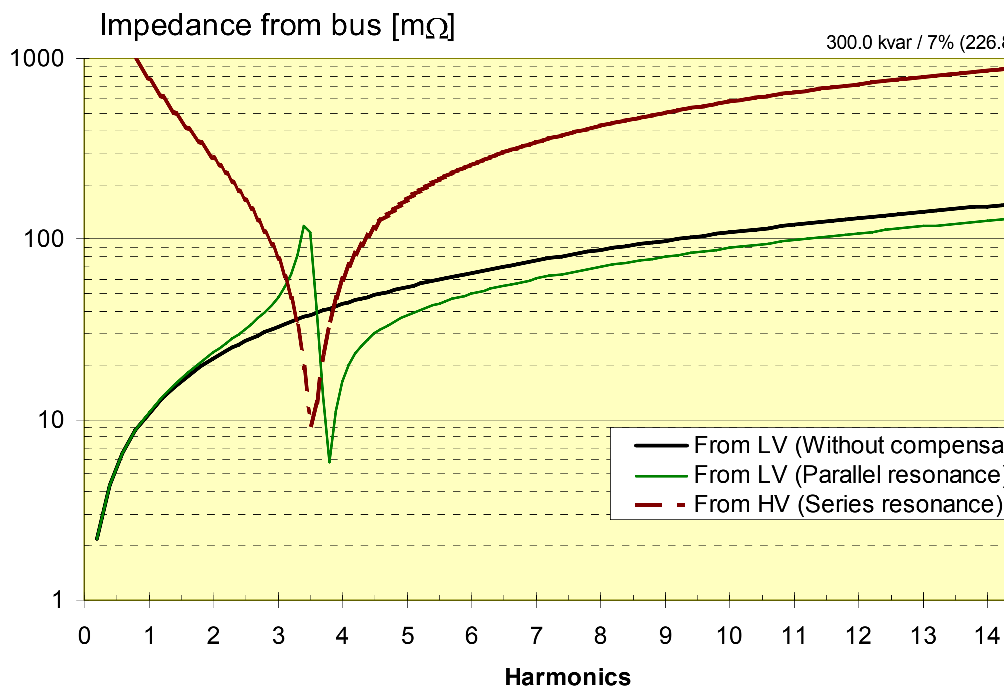
- Gerald to provide

Poor Power Quality

What Impact Does it Have on You?

HARMONICS

- Low Voltage Applications



Poor Power Quality

What Impact Does it Have on You?

HARMONICS Definition (... but <u>please forget it!</u>)

$$f(t) = A_0 + C_1 \cos(\omega t - \phi_1) + \sum_{1}^{\infty} C_k \cos(k\omega t - \phi_k)$$

DC — Fundamental — Harmonics

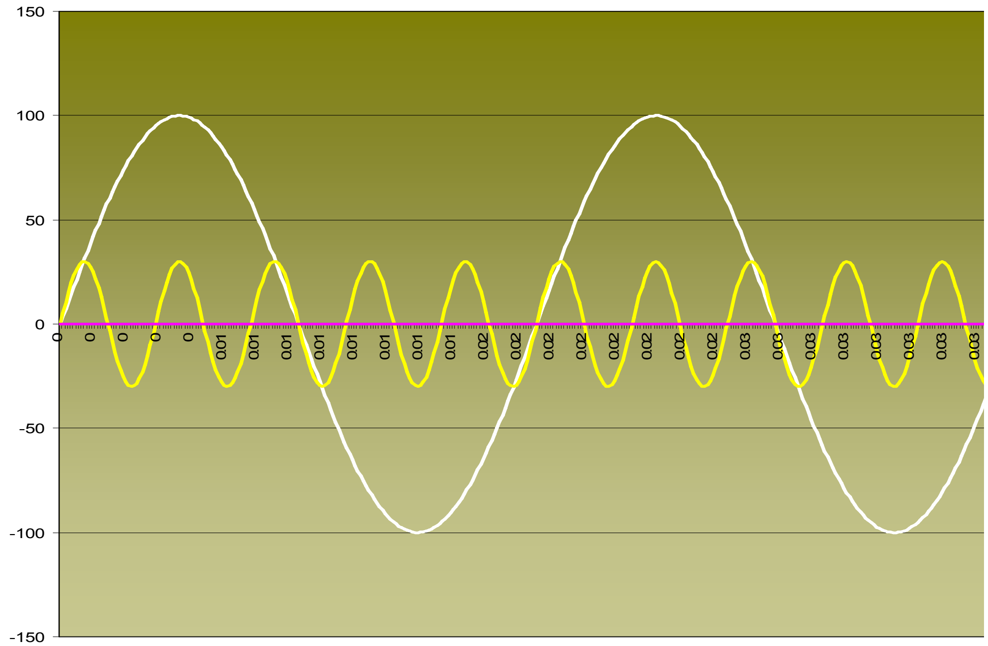
RMS value = $\sqrt{\frac{1}{T}\int_{\theta}^{\theta+T} f^2(t).dt} = \sqrt{A_0^2 + \frac{1}{2}\sum_{k=1}^{\infty} C_k^2}$

Example: No harmonics ⇨ RMS = $C_1 / \sqrt{2}$

Poor Power Quality
What Impact Does it Have on You?

HARMONICS - Definition

Harmonic	%
Fund	**100**
5th	**30**
7th	0
11th	0
13th	0

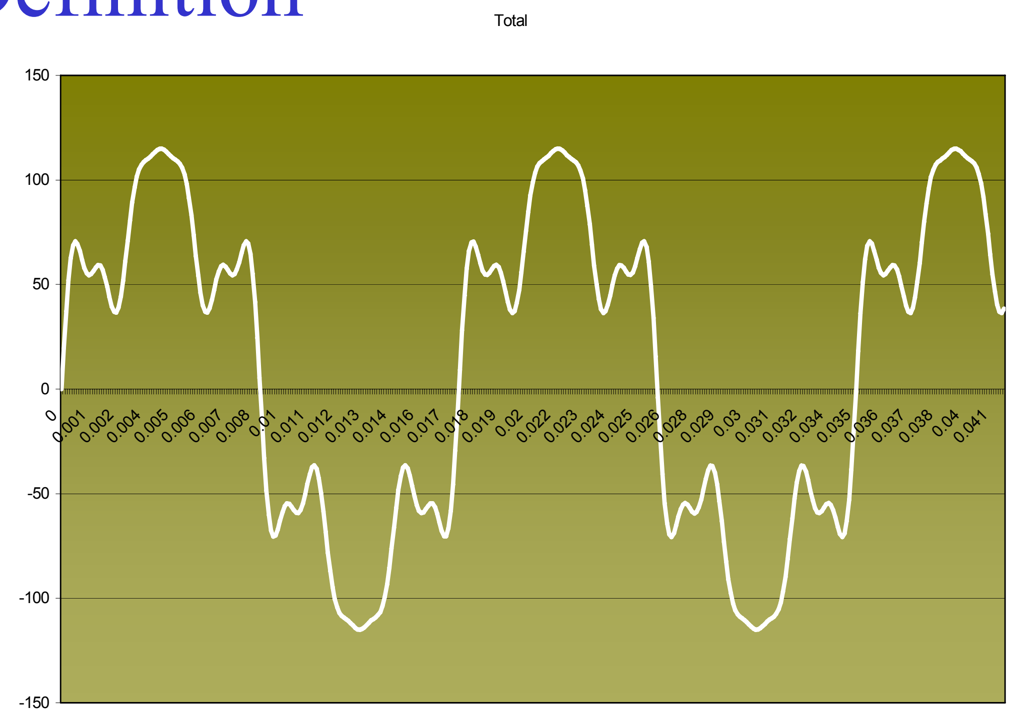


Poor Power Quality

What Impact Does it Have on You?

HARMONICS - Definition

Harmonic	%
Fund	**100**
5th	**30**
7th	**14**
11th	**9**
13th	**8**



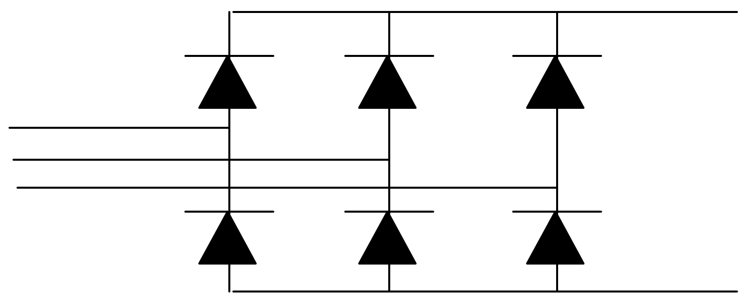
A continuous distortion of the current waveform contributed in multiples of the fundamental.

Poor Power Quality

What Impact Does it Have on You?

Where do harmonics come from?

Non Linear Loads



- AC & DC Drives
- UPS Systems
- Rectifiers
- Softstarters during start-up

- Produce 5th, 7th, 11th 13^{th}..harmonics

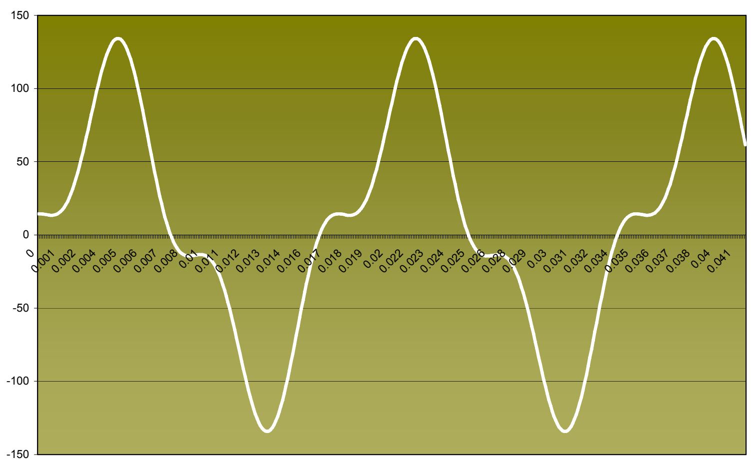
$h = cn \pm 1$

Poor Power Quality

What Impact Does it Have on You?

Where do harmonics come from?

Non Linear Loads



- Computers & Other single phase loads
- Produce also 3rd, 6th, 9th harmonics

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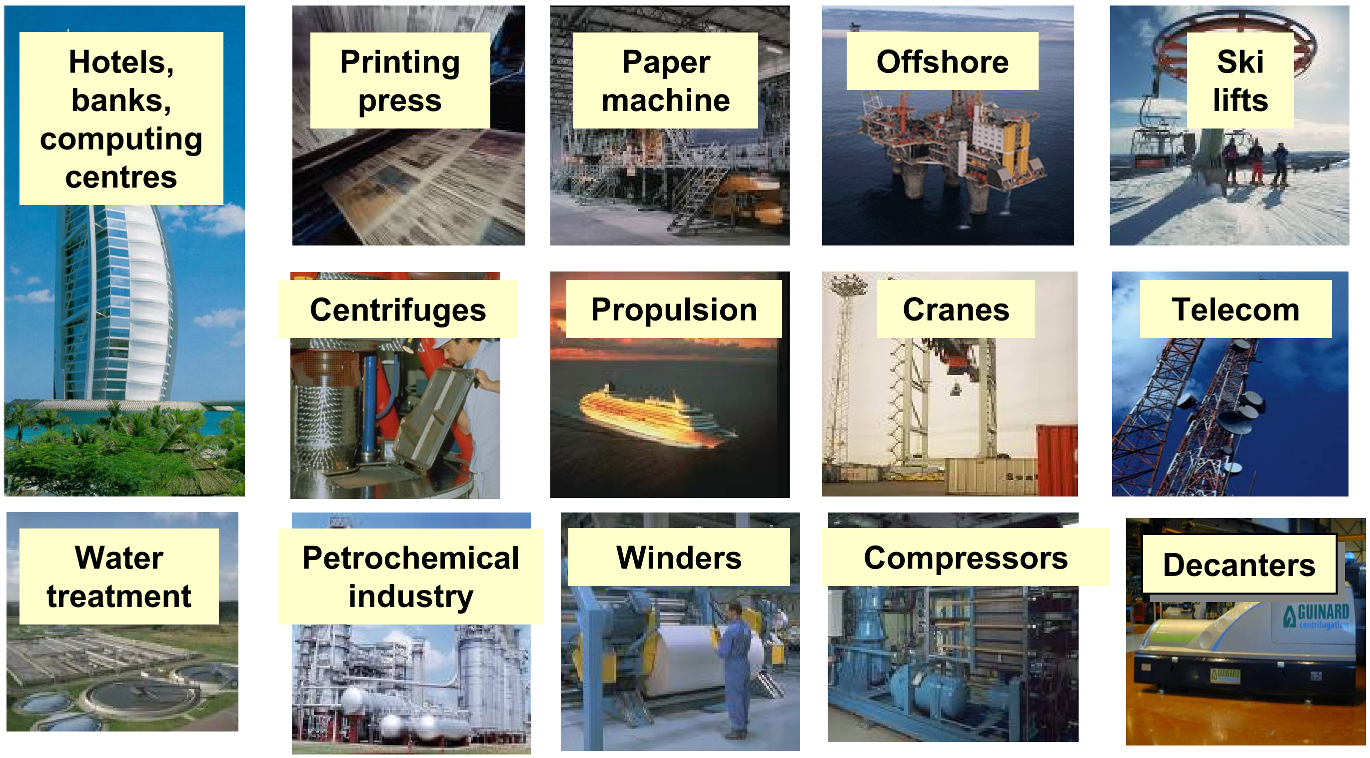
Poor Power Quality

What Impact Does it Have on You?

Where do harmonics come from?



Non-linear loads are everywhere and in ever increasing number!

Poor Power Quality
What Impact Does it Have on You?

Financial and environmental impact of harmonics

Examples

	Losses/ year	CO_2 emissions/year
Small/medium transformers	3000 € ($4,200)	30 T
Large transformers	10000 € ($14,000)	100 T
LV cables (per 100 m)	1500 € ($2,100)	15 T
Motors	10% additional losses	10% additional emissions

Note: Actual results may be different from examples. Values given do not constitute a performance guarantee and depend on local conditions.

Poor Power Quality
What Impact Does it Have on You?

PROBLEMS CREATED by HARMONICS

- Heating of Transformers, Cables & Motors
- Overloading of Capacitors
- Nuisance Tripping of Breakers & Blown Fuses (Down Time!)
- Malfunction of Control Equipment.
- Damage to Sensitive Equipment.
- Non compliance with Regulatory Standards such as IEEE 519.

Poor Power Quality
What Impact Does it Have on You?

WHAT CAN HIGH HARMONIC DISTORTION LEAD TO?

- All electrical devices are designed to operate with pure sinusoidal waves.
- A distorted sine wave may lead to:
  - Lifetime reduction of equipment
  - Damage to equipment
  - Overloading of transformer and cables
  - Malfunctioning of Equipment

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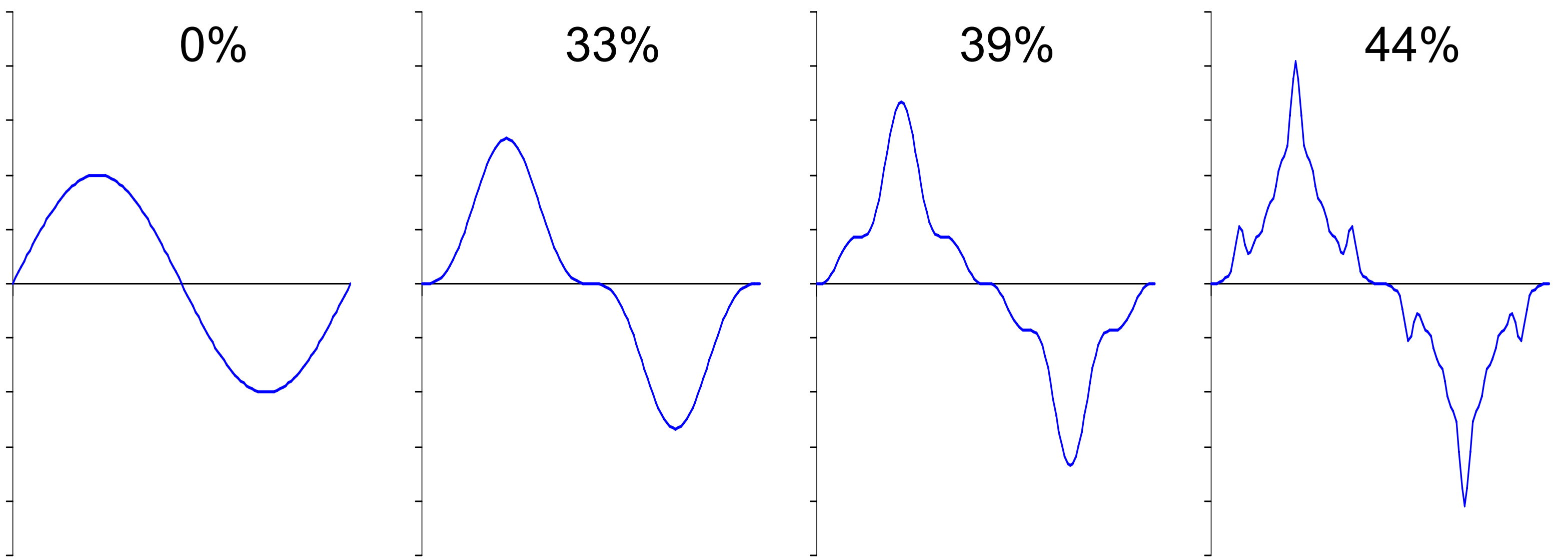
Poor Power Quality

What Impact Does it Have on You?

Effects of harmonics on the waveform

Total harmonic distortion



Peak	100%	133%	168%	204%
RMS	100%	105%	108%	110%

- => Modification of the peak value of the waveform
- => Increase of the RMS value of the waveform

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Poor Power Quality
What Impact Does it Have on You?

PROBLEMS CREATED BY HARMONICS

- Motor problems
  - Additional losses in windings & iron (RMS increase)
  - Perturbing torques on shaft (negative phase sequence harmonics)

Harmonics classification

Order	Group	Effects
n = 1	Fundamental	active power
n = 3k+1	+ sequence	heating
n = 3k-1	- sequence	heating & motor problems
n = 3n	0 sequence	heating & neutral problems

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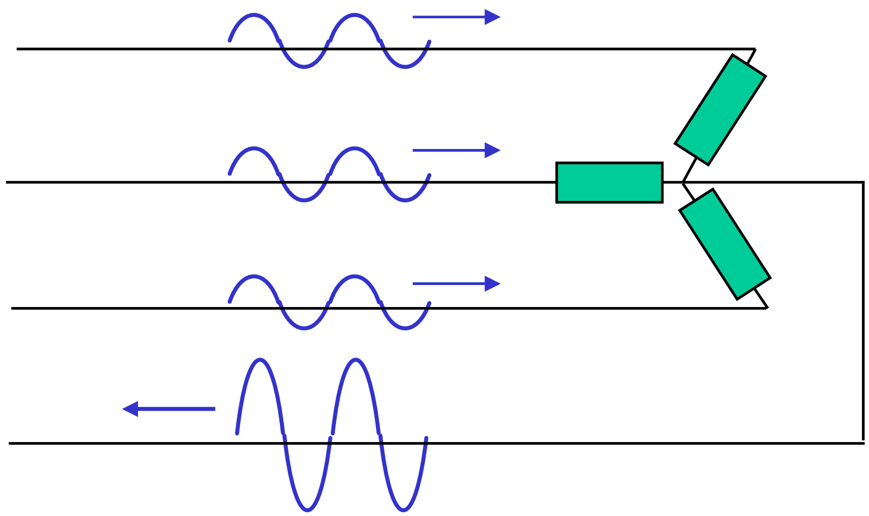
Poor Power Quality

What Impact Does it Have on You?

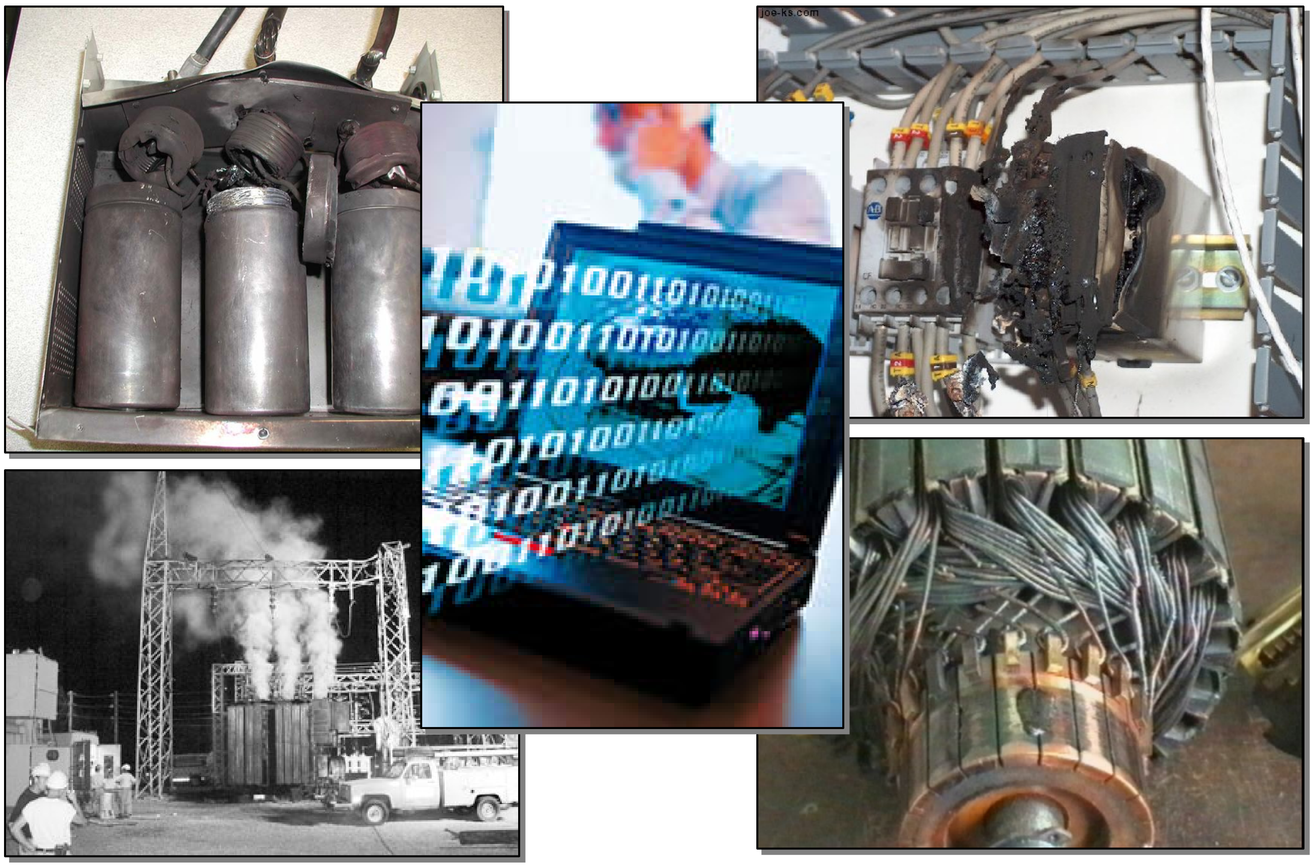
PROBLEMS CREATED BY HARMONICS

- Excessive neutral current (mainly zero-sequence harmonics)



Poor Power Quality
What Impact Does it Have on You?

PROBLEMS CREATED BY HARMONICS

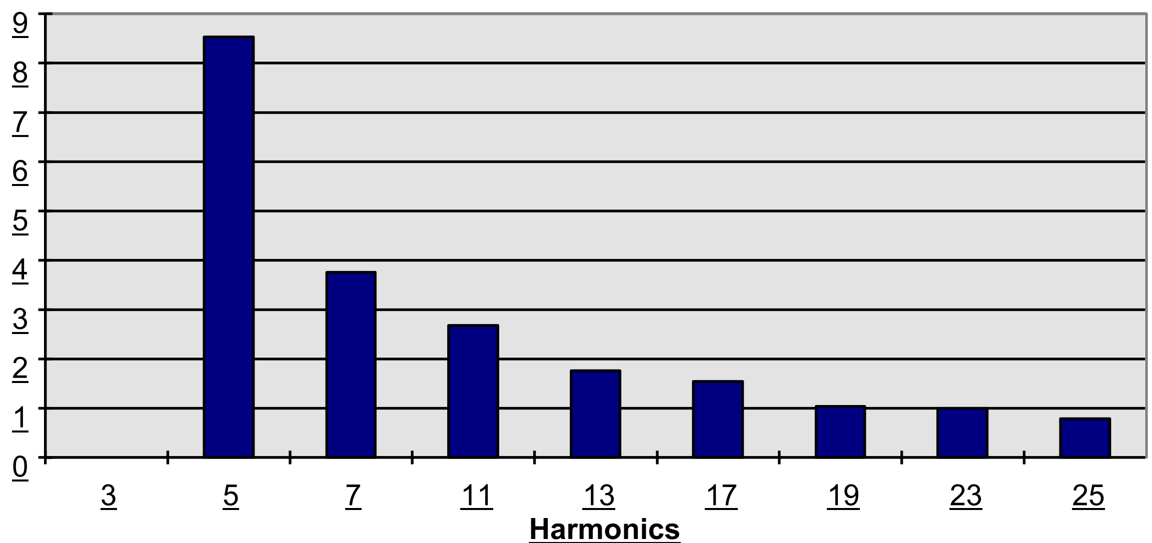


Poor Power Quality

What Impact Does it Have on You?

IEEE - 519 Sets Recommended Harmonic Distortion Limits

- Current limit for the user
- Voltage limit for the utility.



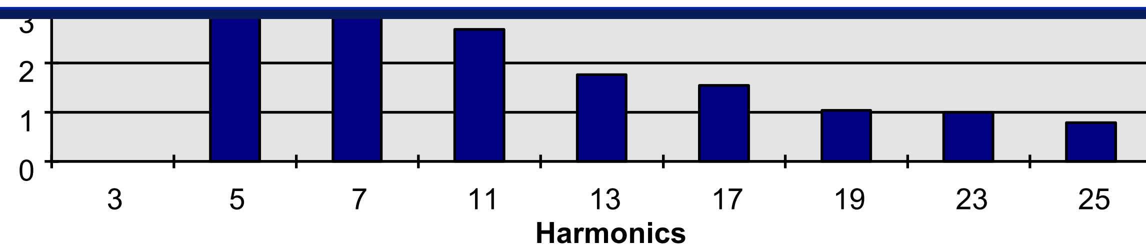
Poor Power Quality
What Impact Does it Have on You?

120V - 69000V

Individual Odd Harmonics

ISc/IL	<11	11<h17	17<h<23	23<h<35	35<h	TDD
<20	4.0	2.0	1.0	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

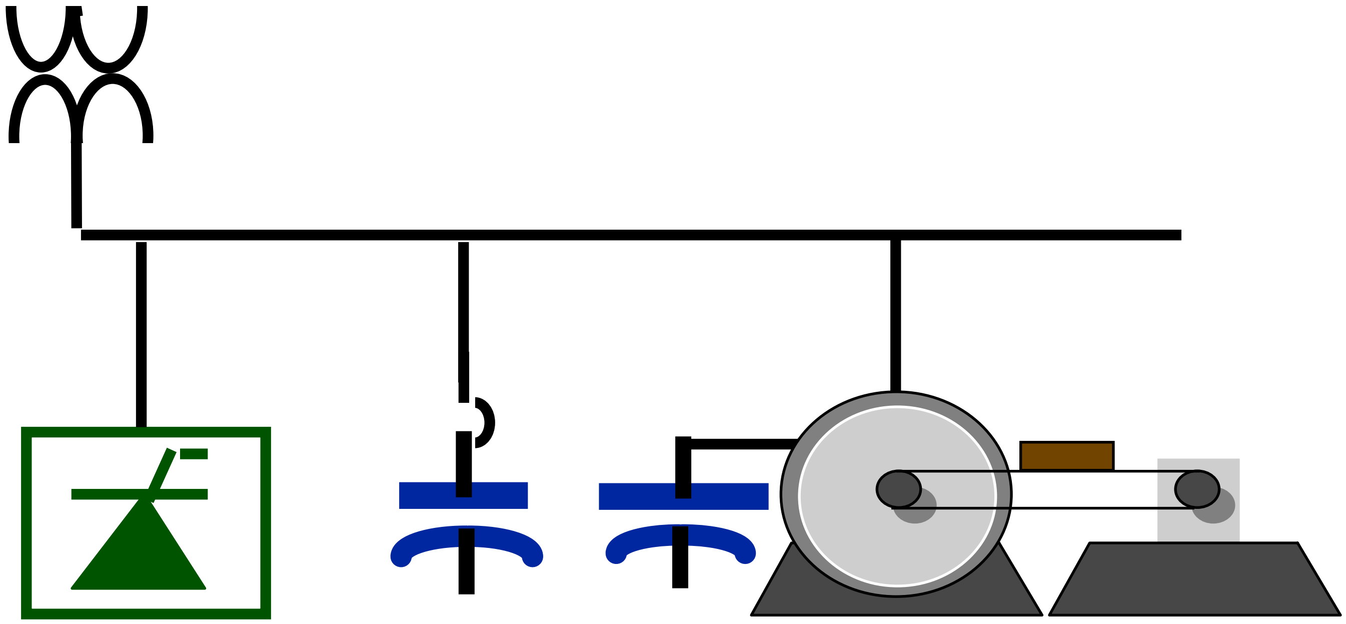
Even Harmonics: 25% of Odd harmonic limits



Poor Power Quality

What Impact Does it Have on You?

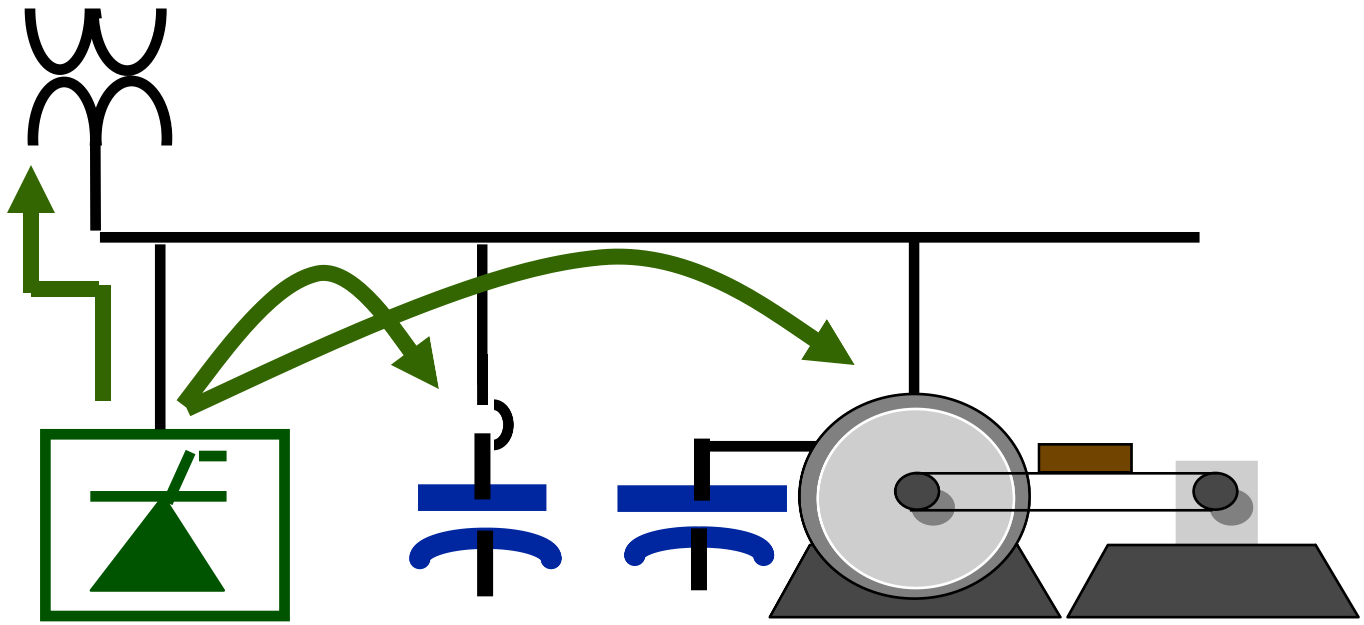
Capacitors in a Harmonic Environment



Poor Power Quality

What Impact Does it Have on You?

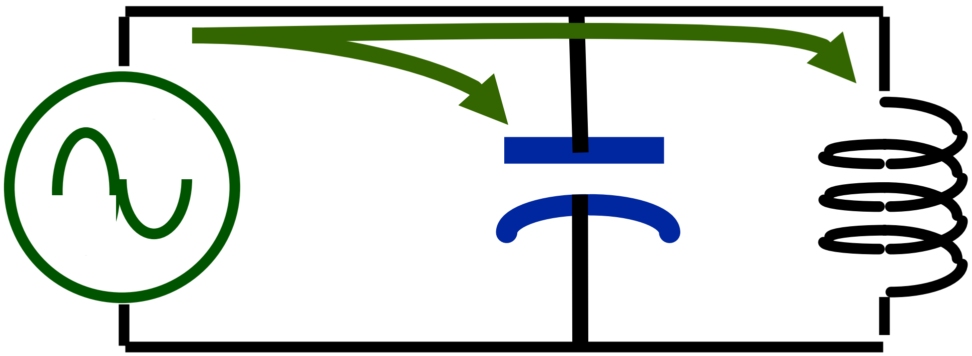
Parallel Resonance



Parallel Paths for Harmonic Current

Poor Power Quality
What Impact Does it Have on You?

Parallel Resonance

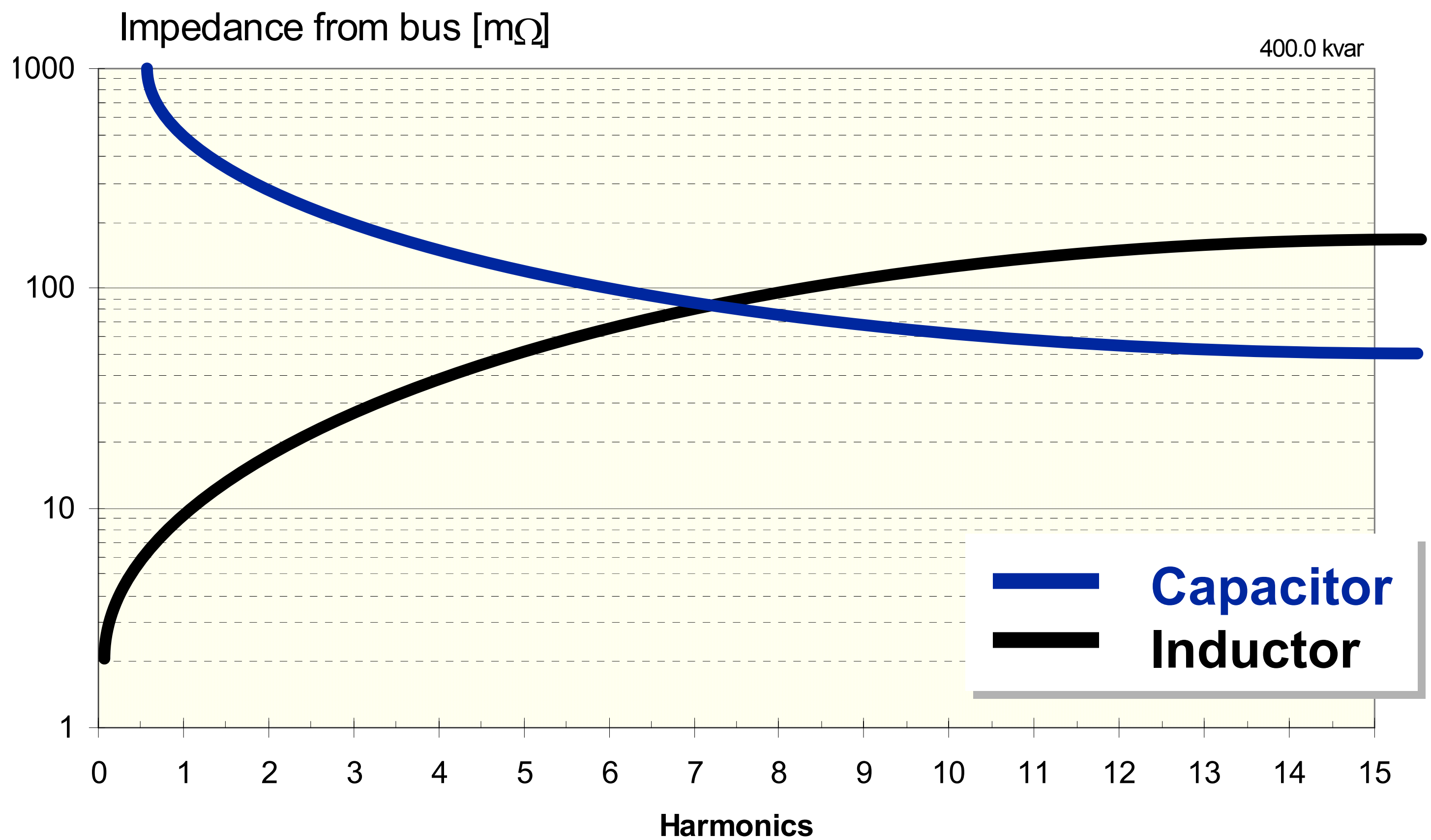


Parallel Paths for Harmonic Current

Poor Power Quality

What Impact Does it Have on You?

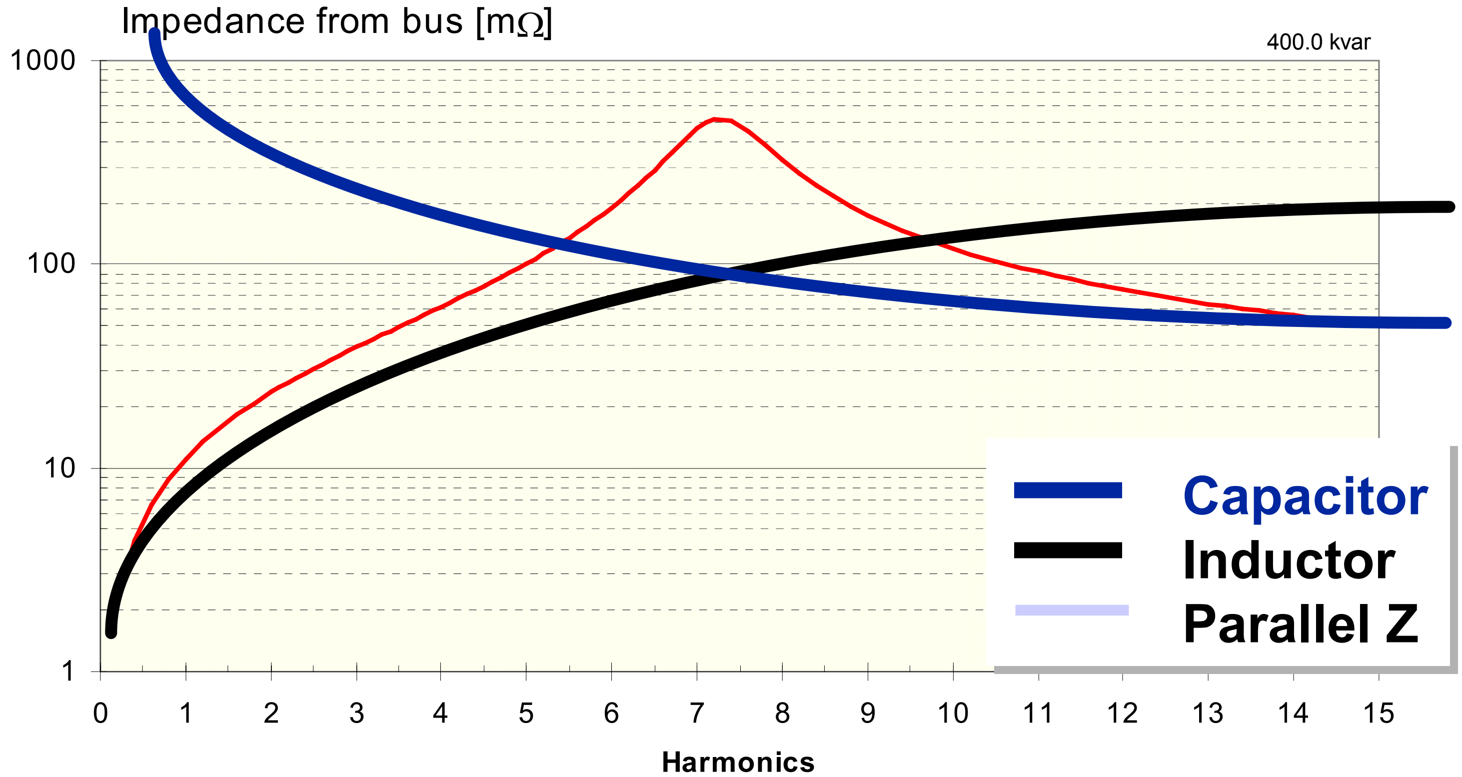
Parallel Resonance



Poor Power Quality

What Impact Does it Have on You?

Parallel Resonance



Impedance at 420 Hz -Increased by 600% !

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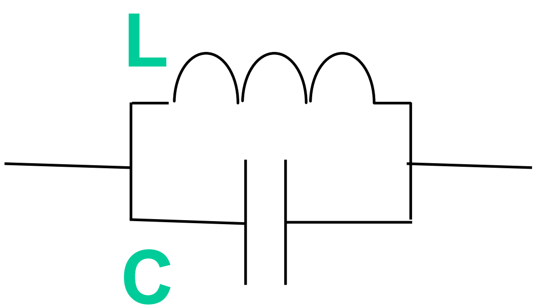
Poor Power Quality

What Impact Does it Have on You?

Parallel Resonance



Impedance:

$$Z(\omega) = \frac{\omega L}{1 - \omega^2 LC}$$

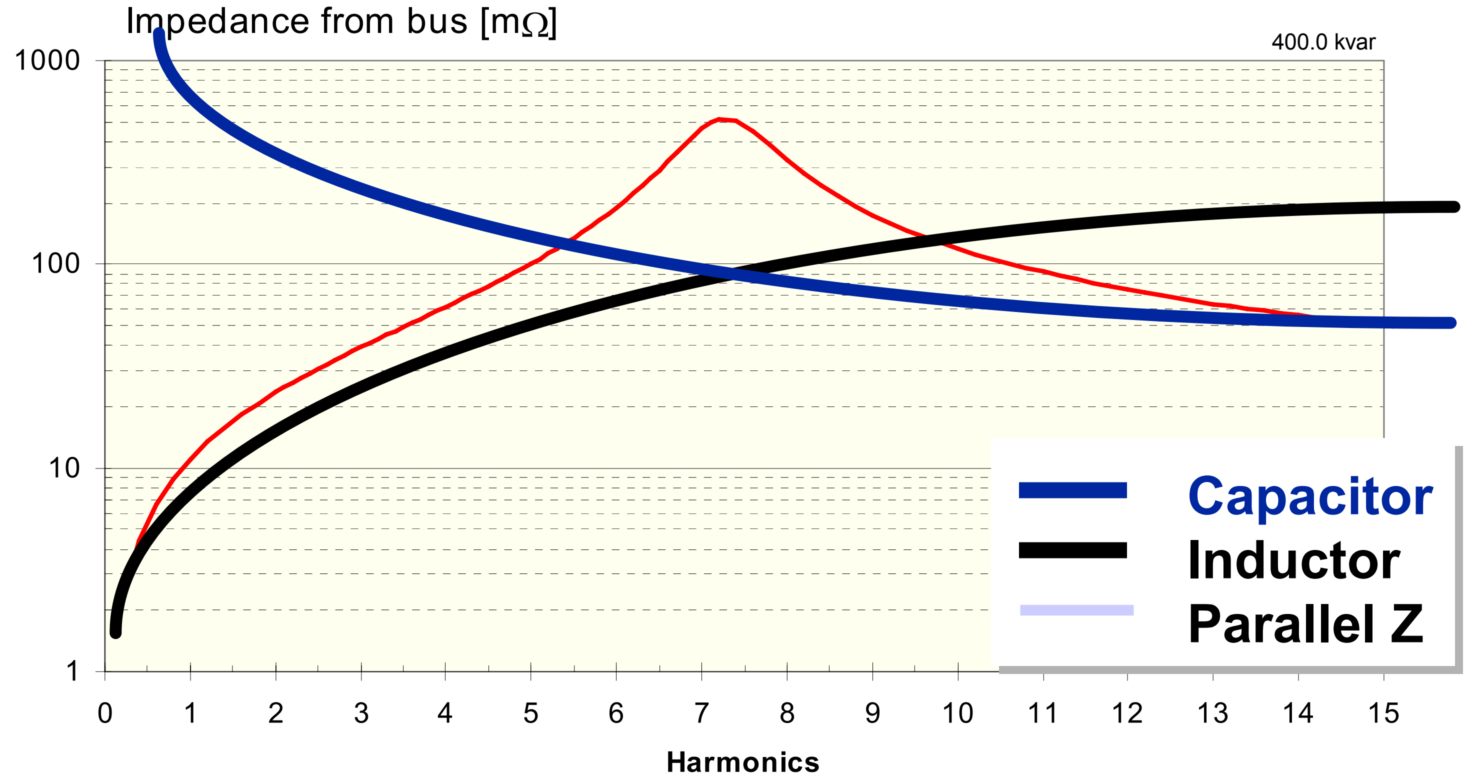
Resonance at frequency ω_0 for which $\omega_0^2\ LC = 1$

$\rightarrow Z(\omega_0)$ = infinity

Poor Power Quality

What Impact Does it Have on You?

Parallel Resonance



Impedance at 420 Hz -Increased by 600% !

Poor Power Quality

What Impact Does it Have on You?

Easy evaluation of resonance

$$n_0 = \sqrt{\frac{S_{scT}}{Q_C}}$$

Short circuit power $S_{scT} = S_T / Z_T$

Capacitor connected power Q_C

Important formula !

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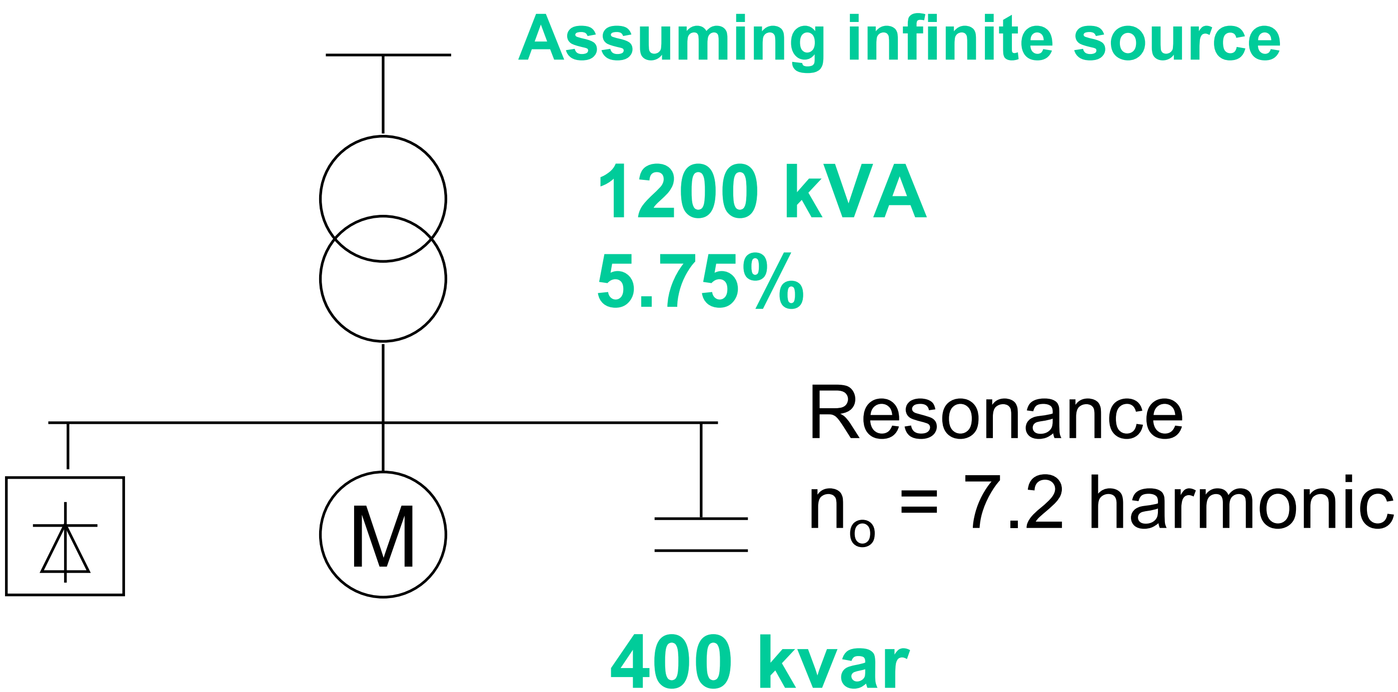
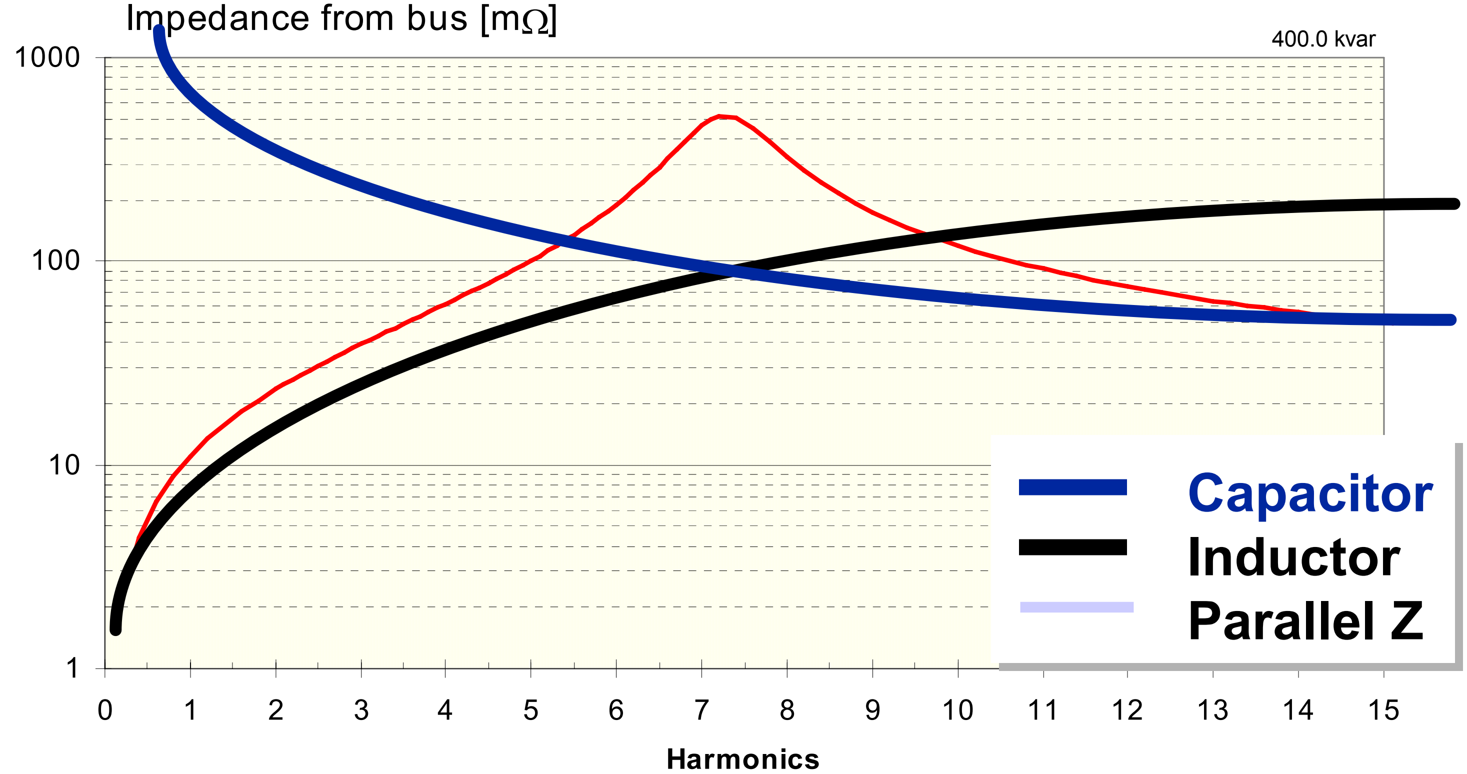
Poor Power Quality
What Impact Does it Have on You?

Typical Example



Poor Power Quality
What Impact Does it Have on You?

Parallel Resonance



Impedance at 420 Hz -Increased by 600% !

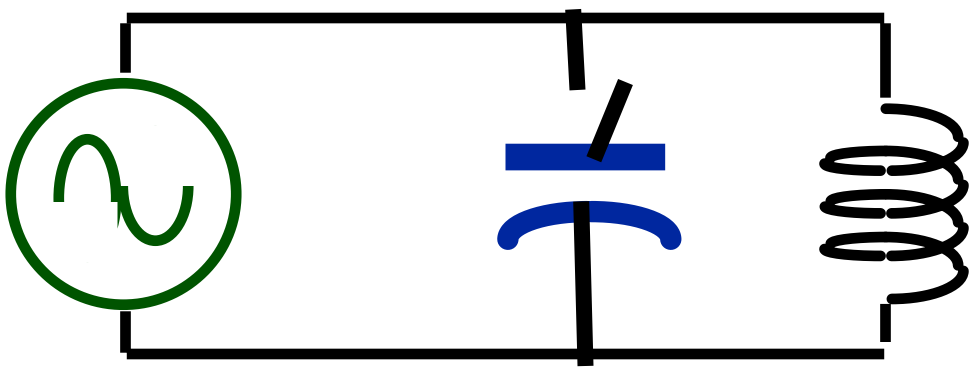
Poor Power Quality
What Impact Does it Have on You?

Parallel Resonance

Impact on Vthd

Assume
V(60Hz) = 277V
I (60Hz) = 240 A
I(420Hz) = 11% = 26.4 A

Since Z(420Hz) without Cap = .08 (80m ohms)



Then
V(420Hz) = .08 x 26.4A = 2.1V
2.1V/277V x 100% = 0.76%

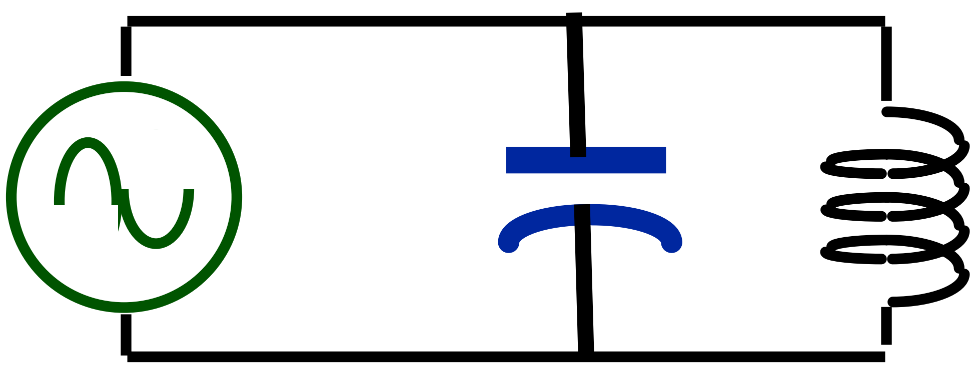
Poor Power Quality

What Impact Does it Have on You?

Parallel Resonance

Impact on Vthd

V(60Hz) = 277V
I(60Hz) = 240 A
I(420Hz) = 11% = 26.4 A

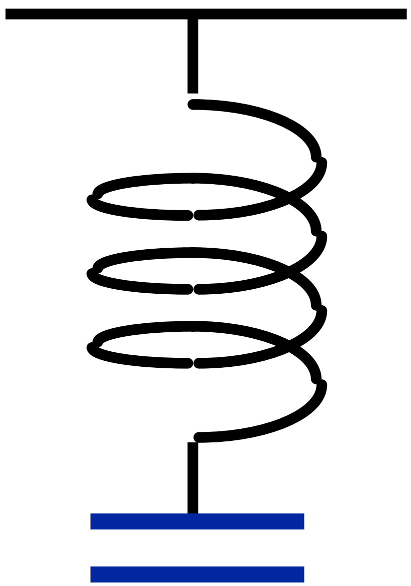


6x.08 =.48 = Z with Cap
26.4Ax.48=12.7V
V(420Hz) = 12.7V
4.6%

Poor Power Quality

What Impact Does it Have on You?

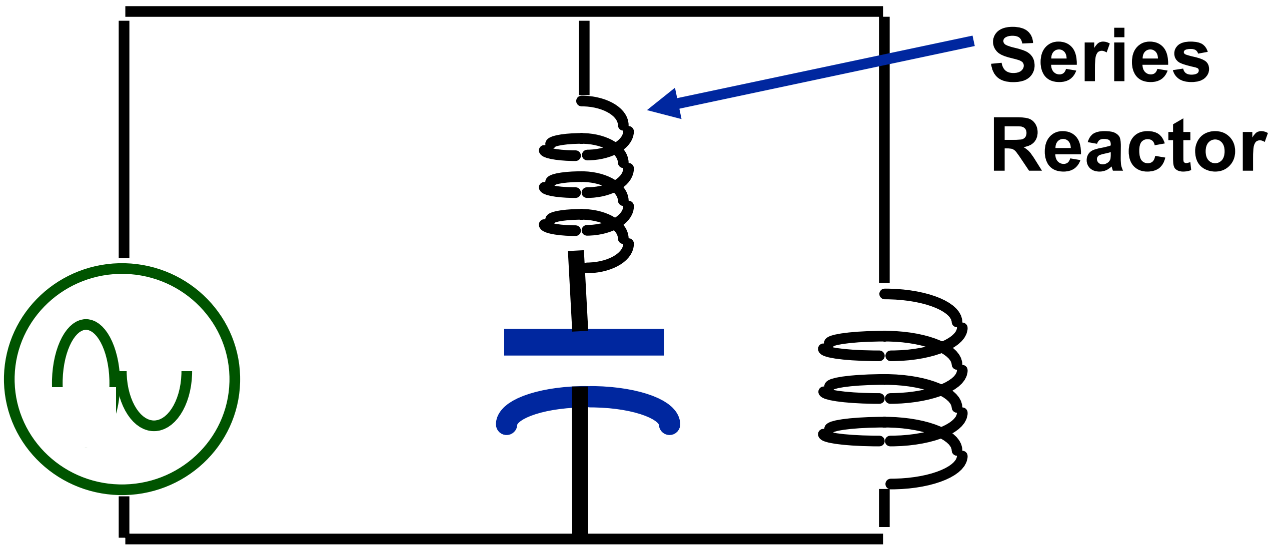
Avoid Parallel Resonance by using Passive Filters



- **Series Connection of a reactor (inductor) and a capacitor, tuned to a chosen frequency.**
- **Provides power factor correction and harmonic filtering.**

Poor Power Quality
What Impact Does it Have on You?

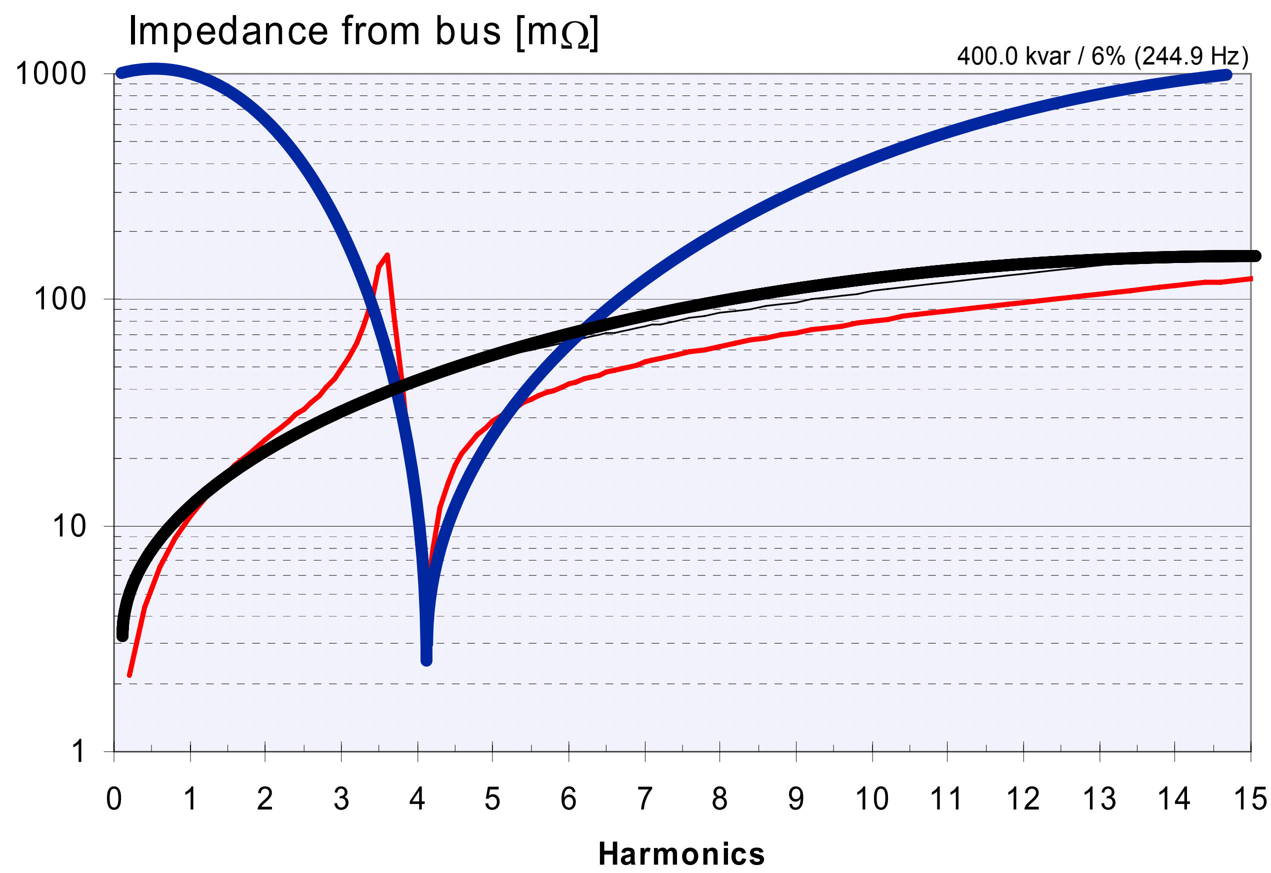
Correcting Parallel Resonance



Poor Power Quality

What Impact Does it Have on You?

Correcting Parallel Resonance

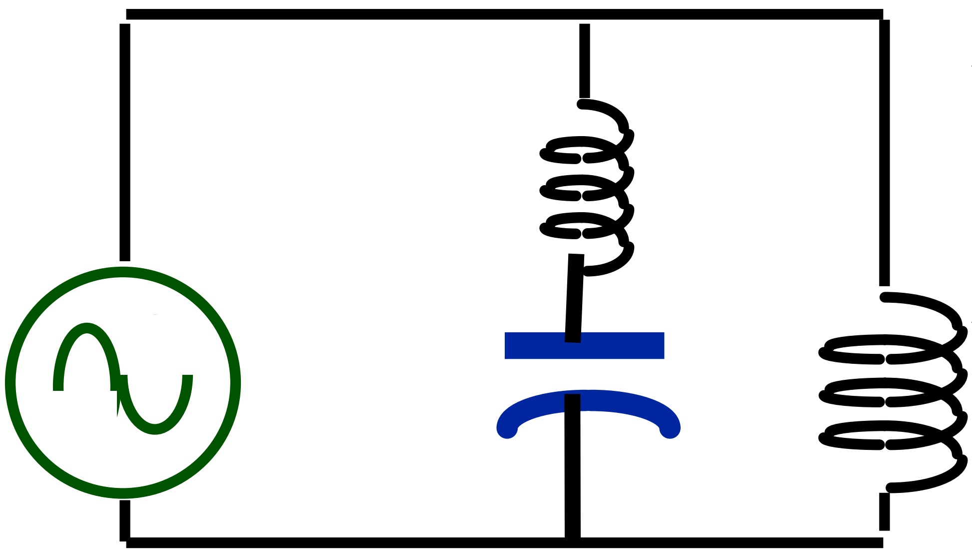


Poor Power Quality

What Impact Does it Have on You?

Correcting Parallel Resonance

I(60Hz) = 240 A
I(420Hz) = 11% = 26.4 A



NOW
Z(420Hz) = 0.053
Z smaller
V(420Hz) = 1.4V
0.52%
BEFORE WITH CAP ONLY
V(420HZ) = 12.7V
4.6%
BEFORE WITH NO CAP
V(420Hz) = 2.1V
0.76%

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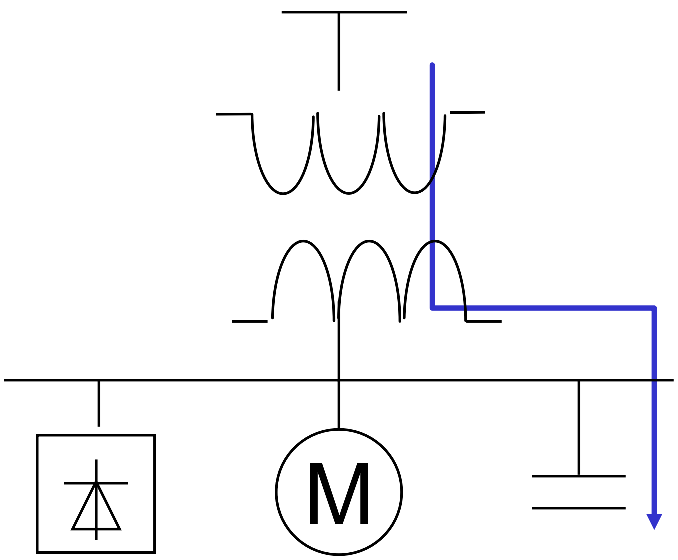
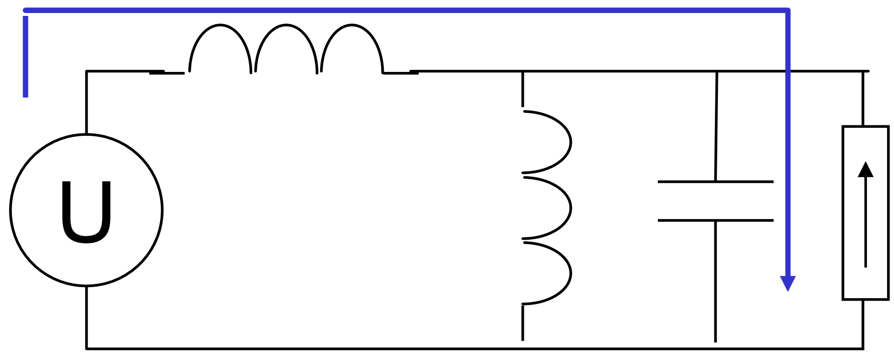
Parallel Resonance now avoided but there still remains yet another concern…

SERIES RESONANCE

Poor Power Quality
What Impact Does it Have on You?

Series Resonance
Harmonics coming from the high voltage network



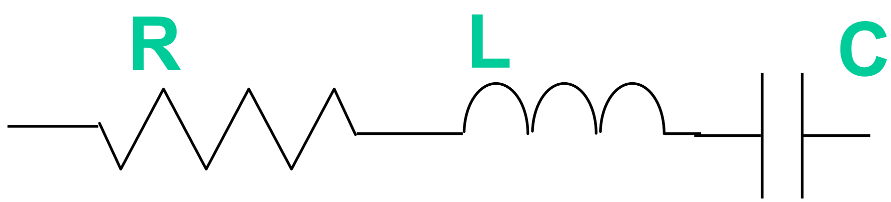


RESONANCE

Poor Power Quality

What Impact Does it Have on You?

Series Resonance



Impedance: $$Z(\omega) = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

Resonance at frequency ω_0 for which $\omega_0 L = 1/\omega_0 C$

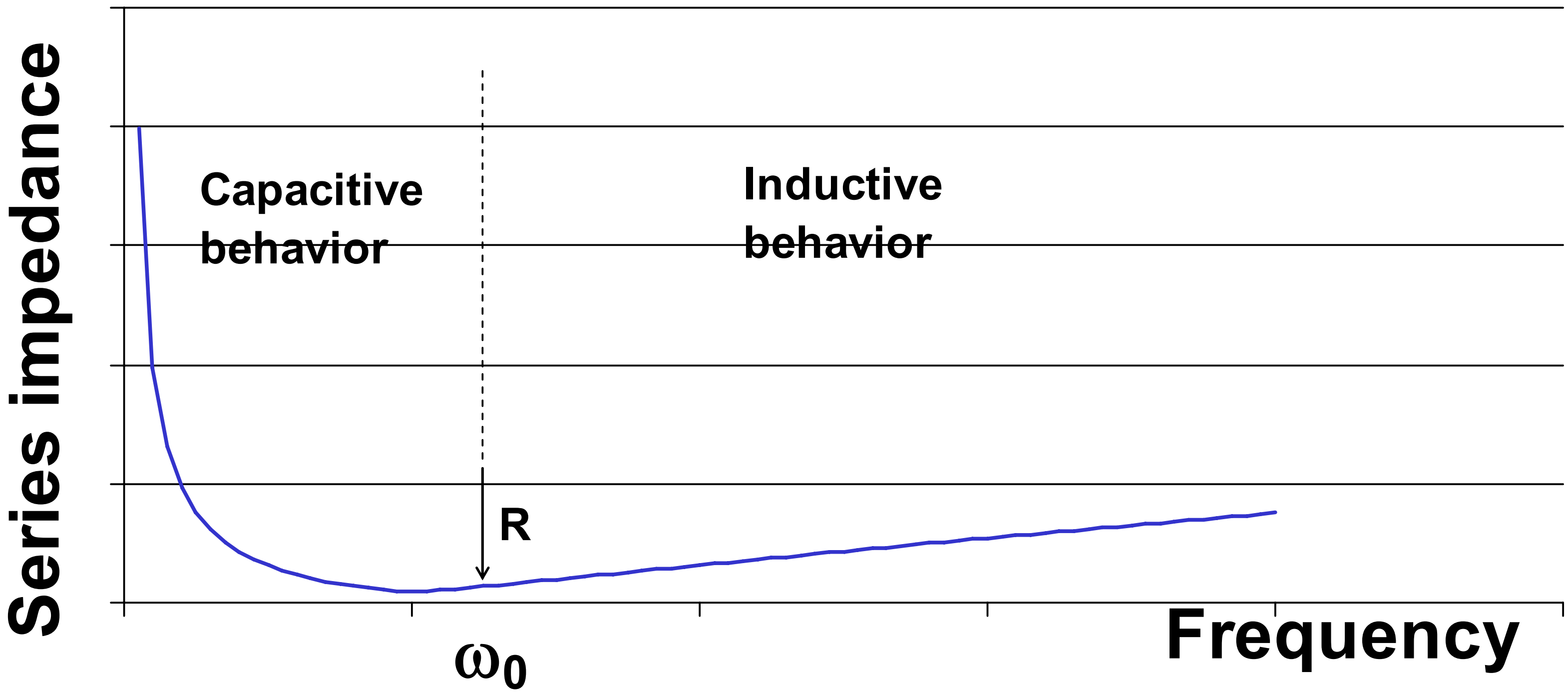
$\rightarrow Z(\omega_0) = R$ ⚠ if R = 0...

$\omega = 2 * \pi * f$

Poor Power Quality

What Impact Does it Have on You?

Series Resonance



Poor Power Quality
What Impact Does it Have on You?

Avoiding Resonance

- Capacitors & inductors will always create parallel and series resonance for some frequency(ies)

  ➡ Resonance is impossible to avoid

- Resonance is not a problem if not excited

  ➡ SOLUTION: **customize** the resonance

Poor Power Quality
What Impact Does it Have on You?

How to customize the resonance?

- By creating resonance only at frequencies where we know there is NO harmonic current.
  - Transformer: fixed (we cannot change)
  - Capacitor: can be both fixed & changing

The Solution:

→ Add a reactor in series with each capacitor

PQ Improvement Equipment Application Considerations and how to design for a safe and durable installation

Poor Power Quality
What Impact Does it Have on You?

Tuned filters

- Tuning very close to a specific harmonic
- Low impedance at this frequency shunting the harmonic
- + High Harmonics absorption

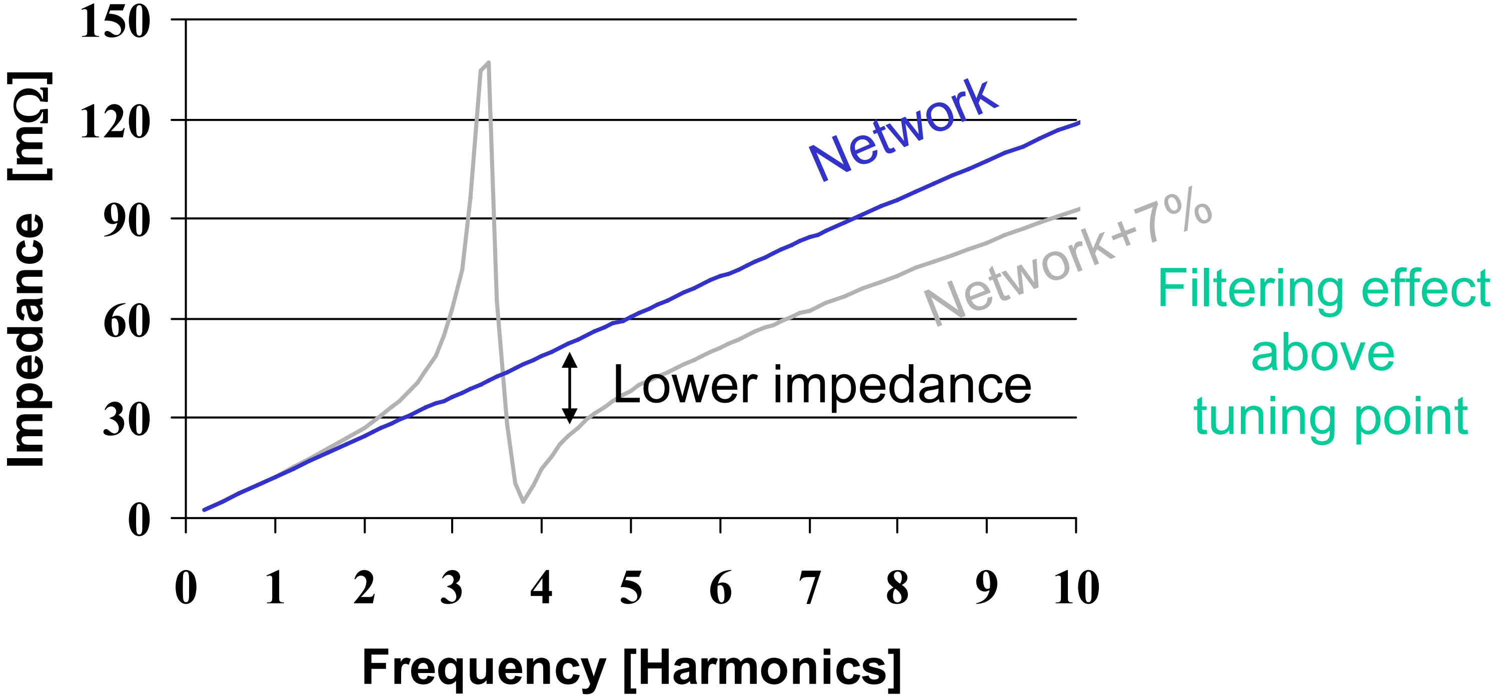
  BUT...

- Very big danger because harmonic current stress can change over time (more nonlinear loads, network impedance changes)

Poor Power Quality

What Impact Does it Have on You?

Filtering effect of Detuned Capacitor Bank

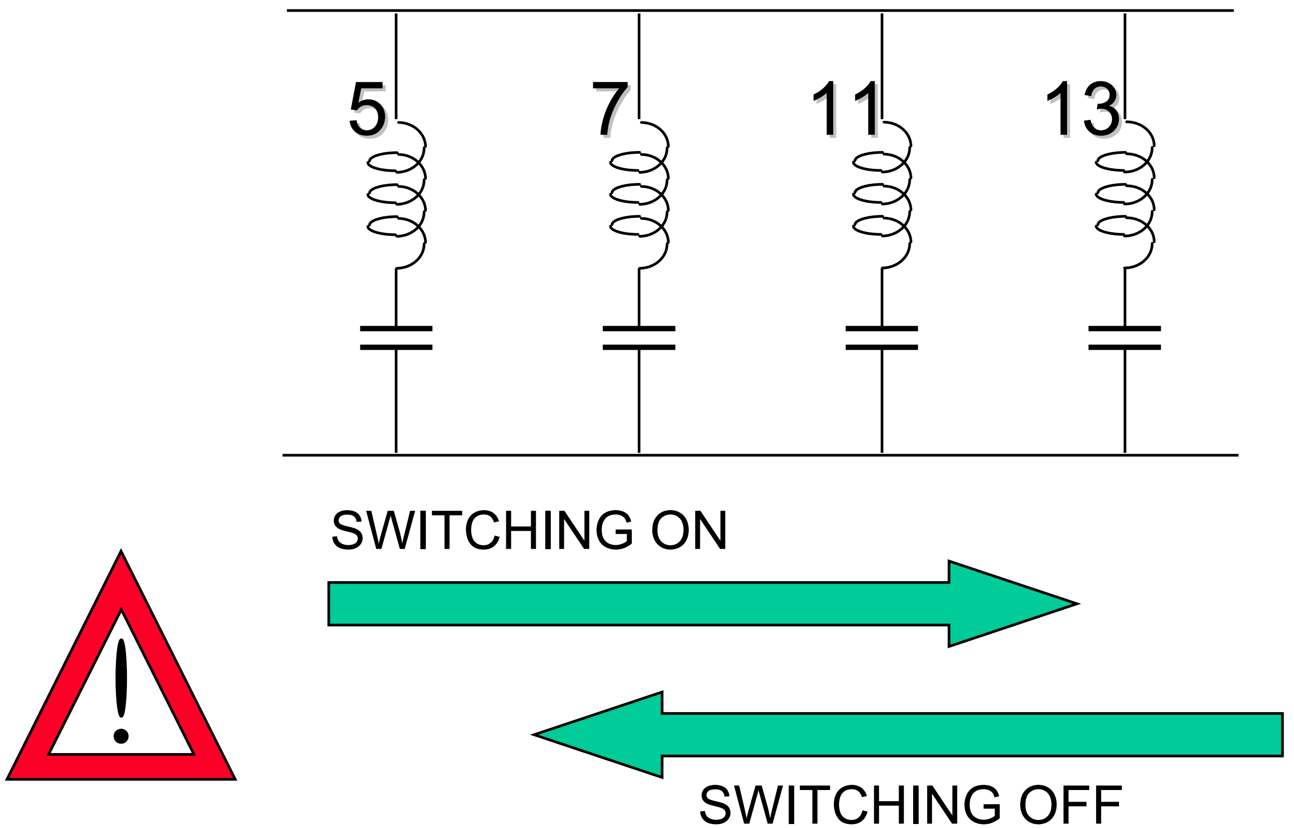


TUNED FILTERS

Special Considerations

Poor Power Quality
What Impact Does it Have on You?

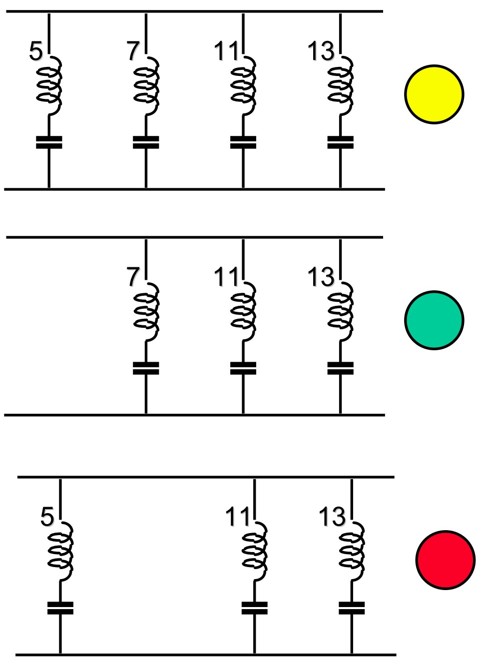
Connection of filter branches in parallel

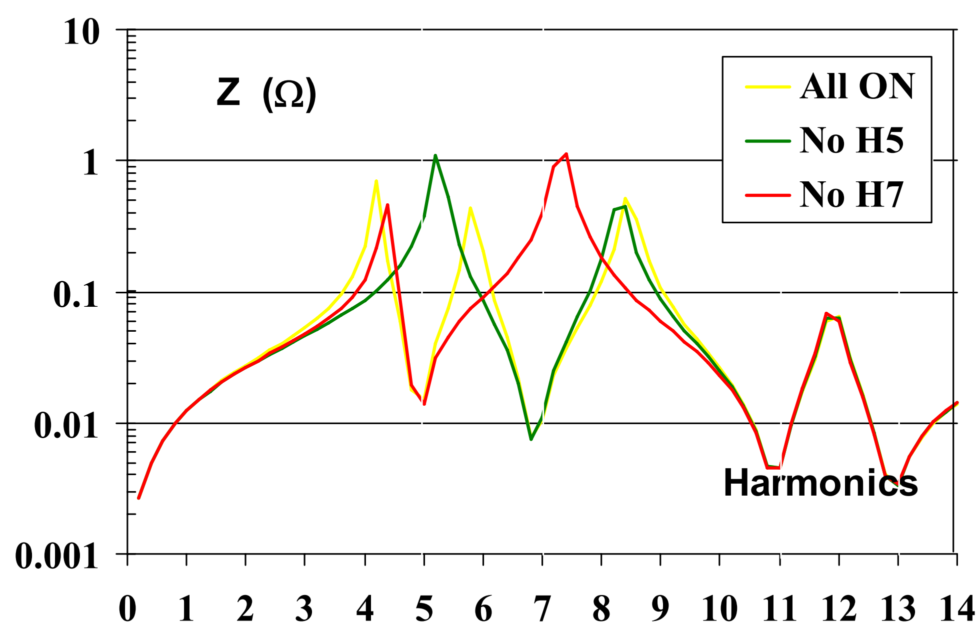


Poor Power Quality

What Impact Does it Have on You?

Connection of filter branches in parallel





➡ Always parallel resonance on missing filter

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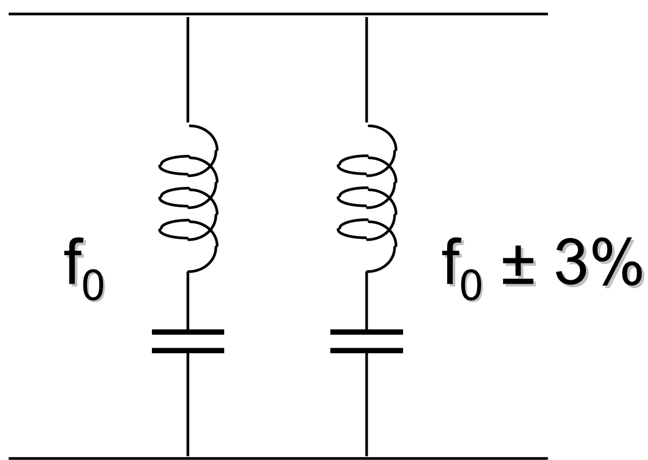
Poor Power Quality
What Impact Does it Have on You?

Connection of same tuned branches

Tolerances
C : ± 5%
L : ± 2%

→ ± 3 % on tuned frequency due to component variations



Very low impedance at f_0

Small differences on Z can lead to very high currents !

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Poor Power Quality
What Impact Does it Have on You?

The Future in Power Quality Improvement, Active Filters

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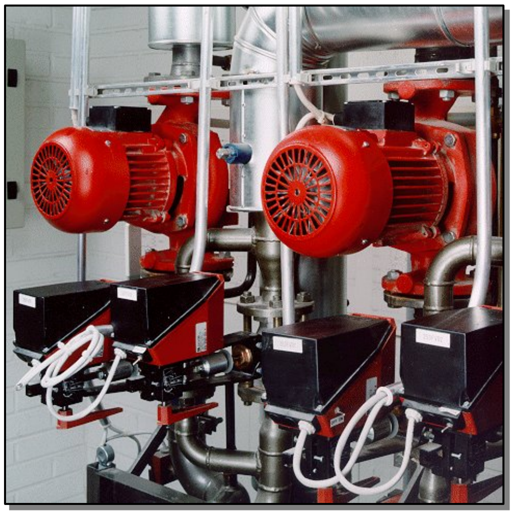
Poor Power Quality
What Impact Does it Have on You?

Traditional solutions to harmonic problems



Structural modifications

- Isolate harmonic sensitive loads from harmonic producing loads
- Use special transformer couplings
- Often only possible in the design phase of the installation or not possible at all

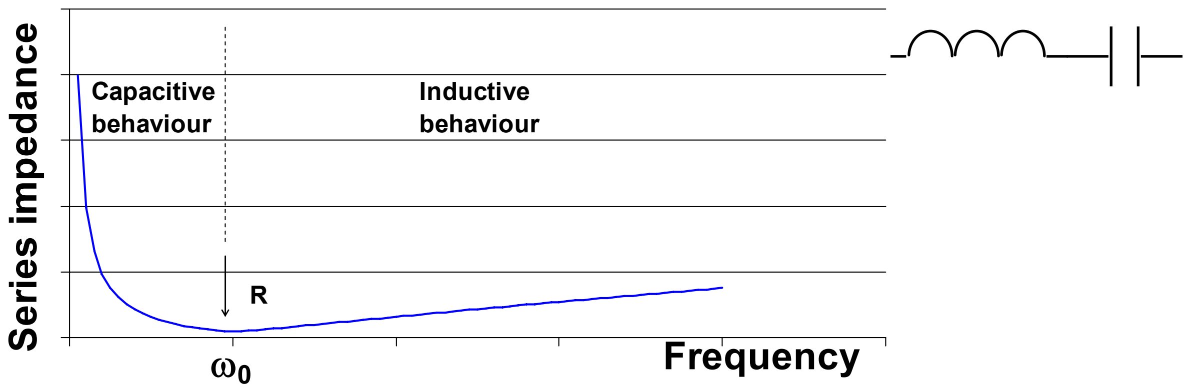
High pulse Drives for industrial loads

- Very expensive with large space requirement

Poor Power Quality

What Impact Does it Have on You?

Traditional solutions to harmonic problems



Passive tuned filters: Reactor and capacitor in series offers low impedance path for harmonic component(s)

- Possible to overload with excessive harmonics
- Multiple branches required for filtering more than one harmonic
- Large weight and physical space requirement

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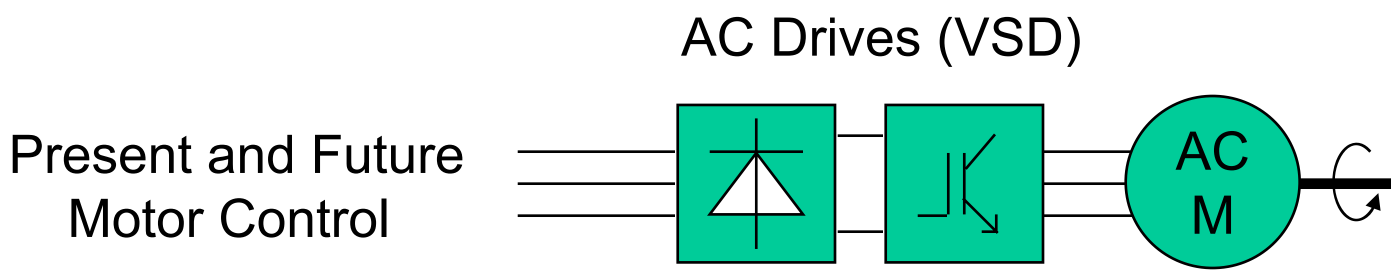
Poor Power Quality
What Impact Does it Have on You?

Traditional solutions to harmonic problems



Passive filters always provide Power Factor correction

- Good displacement power factor (dPF = 95% or higher), However High Harmonics created.
- No capacitors needed to improve the Power Factor but harmonic filtering REQUIRED!

➔ In Low Voltage networks, **passive filters** will be used less and less

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Poor Power Quality

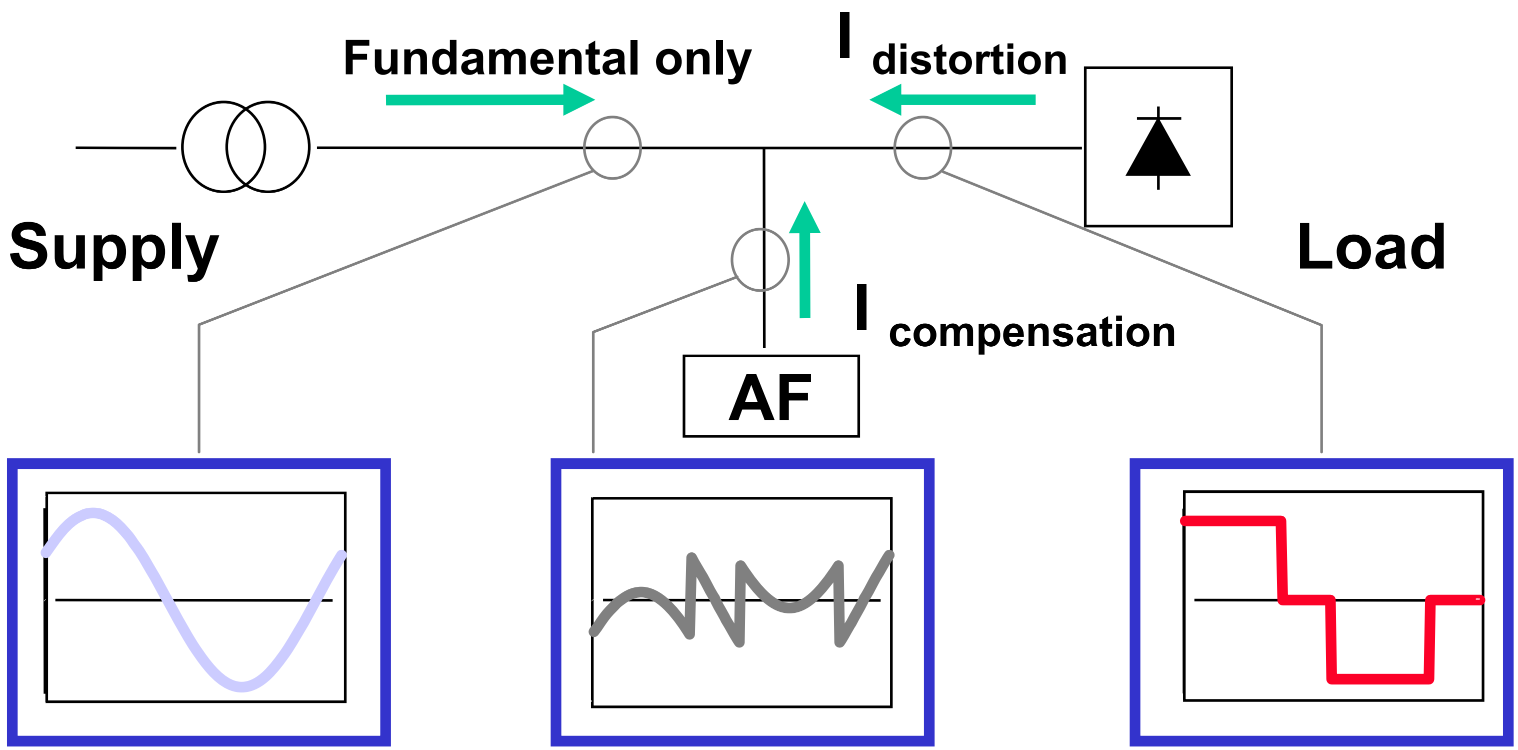
What Impact Does it Have on You?

Conclusion: we need a better solution

- That is not overloadable
- That is flexible (e.g. doesn't have to improve Power Factor)
- That doesn't introduce new resonance frequencies
- That is small and compact
- That doesn't require sophisticated network studies

Poor Power Quality
What Impact Does it Have on You?

The best solution to harmonic problems are Active Filters



Active harmonic filtering principle

Poor Power Quality
What Impact Does it Have on You?

Advantages of ABB Active Filters ?

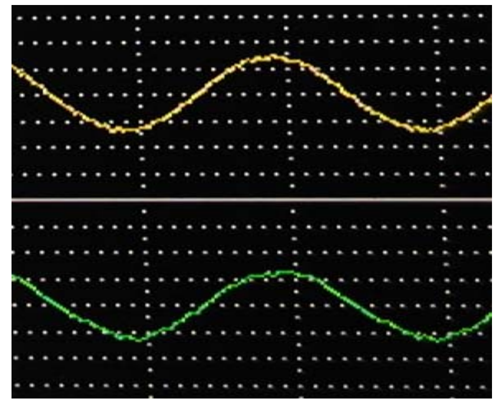
- Filter up to 20 individually selectable harmonics simultaneously in a range up to the 50^{th} harmonic
- Desired harmonic filtering levels can be preset for each individual harmonic
- Cannot be overloaded by excessive harmonics.
- Can perform Power Factor Correction (if desired)
- Load Balancing
- Small space requirement
- Easily expandable

Poor Power Quality
What Impact Does it Have on You?

ABB Active Filter load balancing example

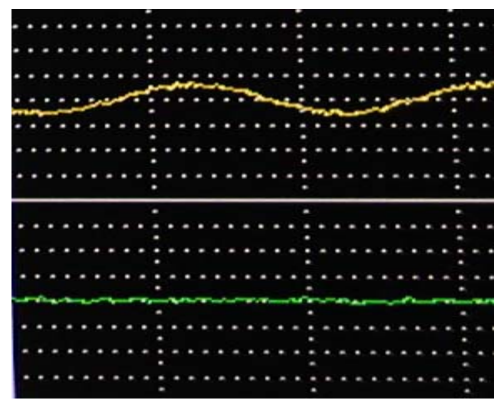
L1: 49.1 Arms
L2: 5.3 Arms
L3: 5.1 Arms

N: 44.1 Arms



L1: 19.6 Arms
L2: 19.4 Arms
L3: 19.5 Arms

N: 3.5 Arms



Poor Power Quality
What Impact Does it Have on You?

Why use ABB Active Filters ?

- ABB active filters can increase the Energy Efficiency of the installation substantially…

  (Two Field Reports)

Poor Power Quality
What Impact Does it Have on You?

Field report 1: Diesel Generator Application

The installation:

Power plant: 2 generators
Main load: 2 DC drive propulsion units

Performance without filters:
G1: 660 A, G2: 580A **dPF: 0.76**
THDV = 22%, THDI = 25%

Avg. diesel fuel consumption: 3800 gal/month

- **The inquiry**
  - Install filters to solve harmonic problems due to propulsion DC drives
  - Perform PF correction without overcompensation

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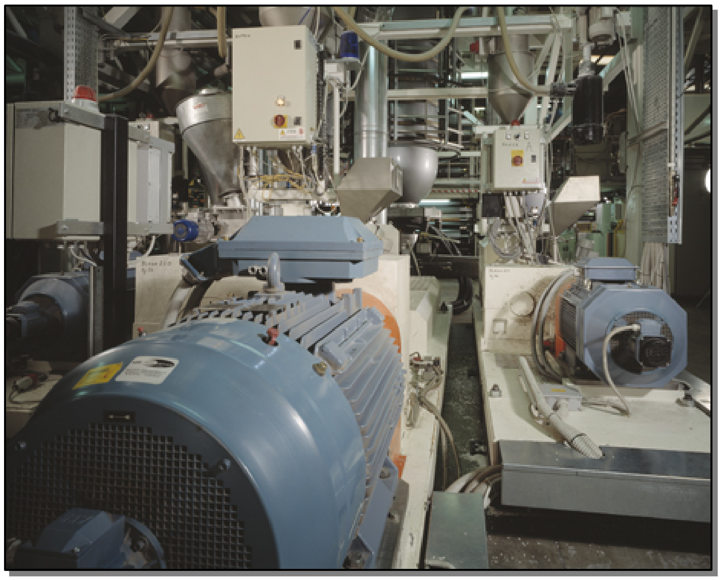
Poor Power Quality
What Impact Does it Have on You?

Field report 1: Diesel Generator Application

- **Reasons for choosing ABB active filters**
  - Compact solution (paramount given the limited space aboard)
  - Excellent filtering performance
  - Possibilities to perform automatic transient-free power factor correction
  - ABS (American Bureau of Shipping) and BV (Bureau of Veritas) offshore certification
- **Customer findings and consequent actions**
  - Technical problems resolved
  - With ABB PQF active filters operational, approx. 10% fuel savings were reported resulting in drastically reduced running costs
- ***Customer gain: per ferry approx. 4,800 gallons fuel/year***

Poor Power Quality
What Impact Does it Have on You?

Field report 2: Industrial extruder lines



Customer

- Runs various extruder lines resulting in THDV of about 11% on LV side
- Extruder lines are DC drive based
- Due to the harmonics in the voltage, voltage wave form had multiple zero crossings which upset the DC drive control causing damage
- Hopes to have reduction of losses in (long) feeding cables and feeding transformers (billing aspect and cable overheating aspect)

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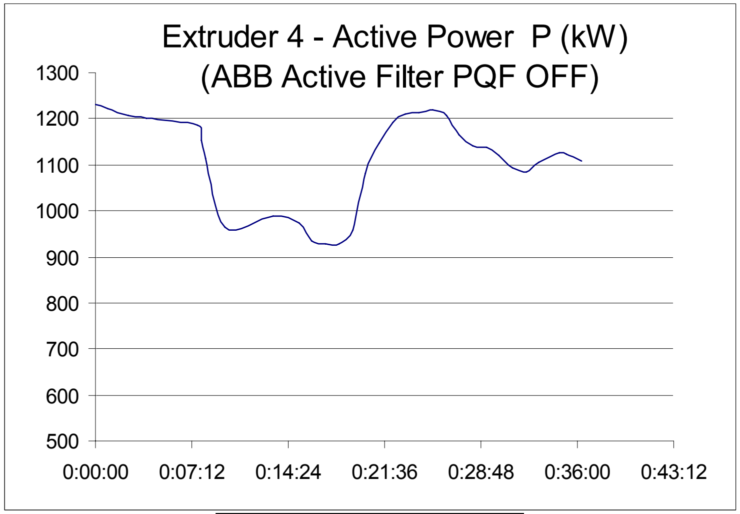
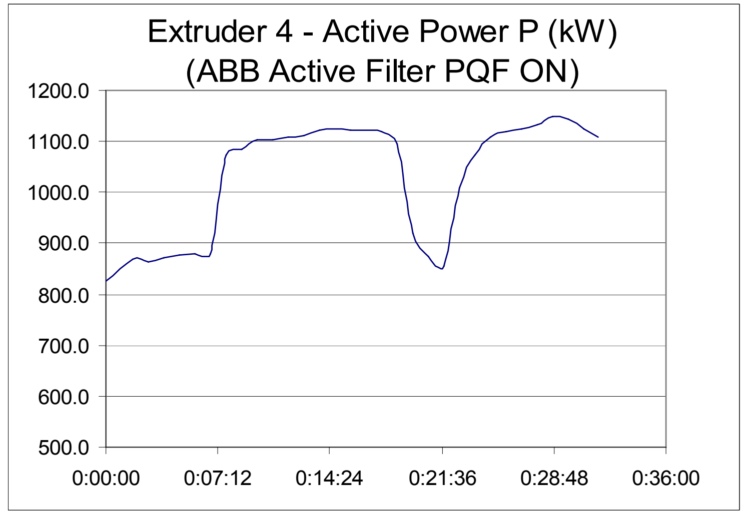
Poor Power Quality
What Impact Does it Have on You?

Field report 2: Industrial extruder lines



P_{min} = **927 kW**
P_{max} = **1230 kW**



P_{min} = **827 kW**
P_{max} = **1147 kW**

Customer findings and consequent actions

- **Technical problems in production line disappeared**
- **PF of the installation increased from 0.84 to 0.92 on average**
- **In house on-line power consumption monitoring indicated around 10-15% savings of active power which resulted in very short pay back time of installation**

Poor Power Quality
What Impact Does it Have on You?

Field report 2: Industrial extruder lines

- ABB verification measurement with high precision measuring equipment indicated that measuring equipment used by the company functions correctly
- Results - 11% power savings were recorded with filter running
- ABB contacted independent 3rd party European accredited measurement laboratory, ‘Labo Lemcko‘ to re-measure and verify the validity of the measurements made...

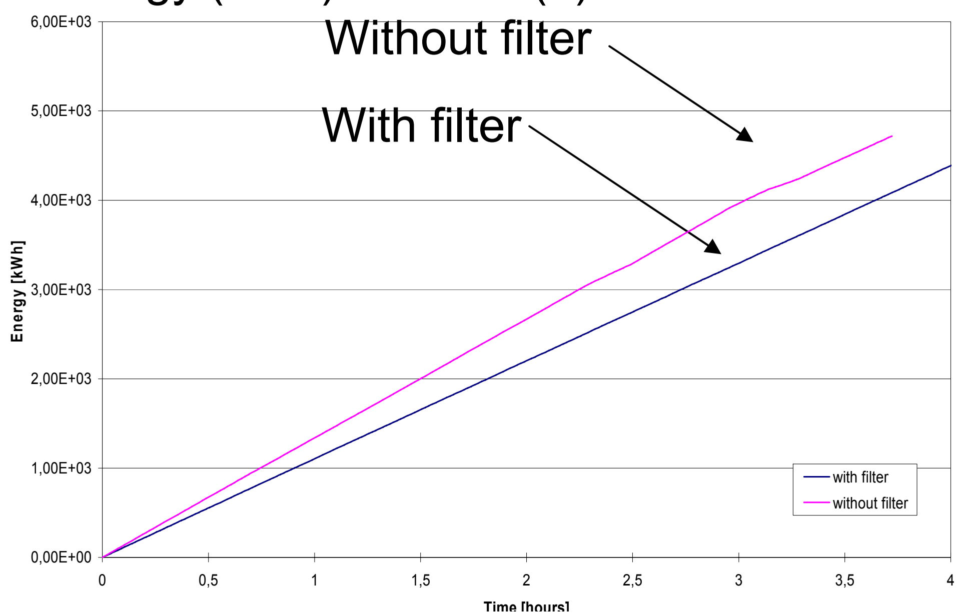
Poor Power Quality

What Impact Does it Have on You?

Field report 2: Industrial extruder lines

- Independent laboratory confirmed 14.5 % energy savings!

Energy (kWh) vs Time (h)



Customer gain: more than $70,000 per year!

Poor Power Quality
What Impact Does it Have on You?

Field report 2: Industrial extruder lines

Financial analysis over time

Yr	Accumulated energy savings (USD)
1	>$70,000
2	>$140,000
3	>$210,000
4	>$280,000
…	…
Note: during the first year, the customer has already profited because the production line down time is reduced.	

Year 1: Pay-back time

Years 2–4: Additional profit

Very short pay-back time is realized!

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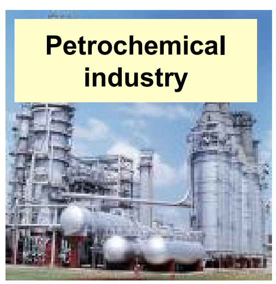
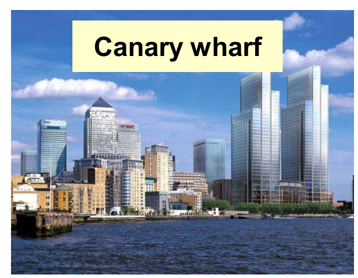
Poor Power Quality
What Impact Does it Have on You?

Where are active filters used?





…everywhere Power Quality is at stake!!!

Power and productivity
for a better world™

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