Harmonics mitigation and solutions

Schneider Electric

Summary

I. Introduction

II. Harmonics mitigation solution

III. Case study

IV. Conclusion

I. **Introduction**

II. Harmonic mitigation solution

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IV. Conclusion

I. Introduction

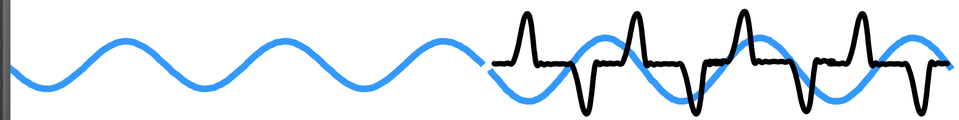
- The quality of electrical power is determined by the voltage
  - High-quality voltage is the best guarantee for continuous operation of equipment

The voltage signal must be perfect at the source...

... because distortion may occur at the end of the line

Line impedance
Type of installation
Length of cables
Internal impedance of equipment...

The harmonic current from the load
Type of load
Power supply technology



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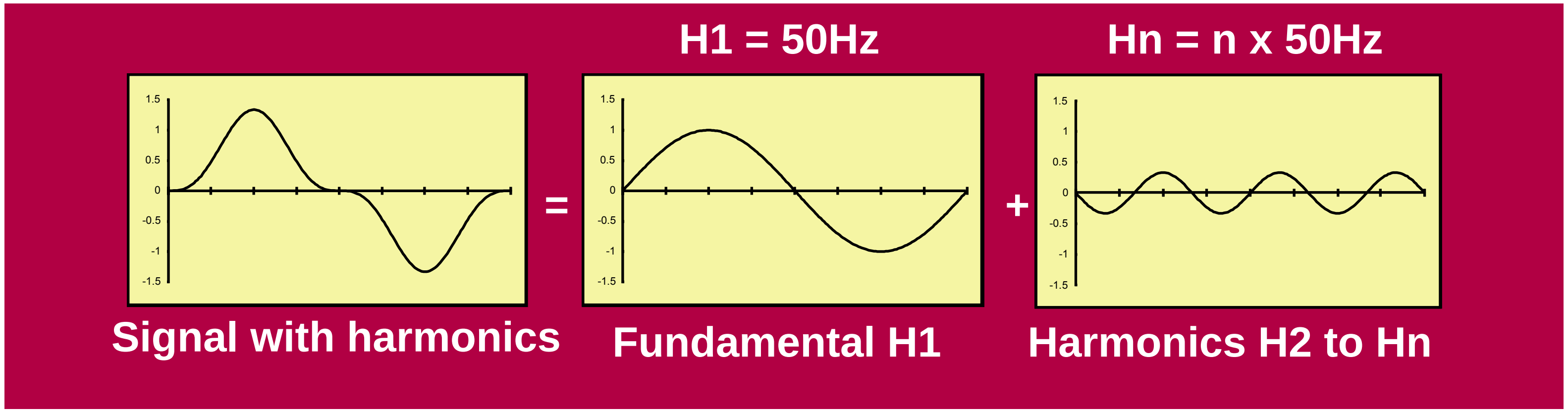
II. What is a harmonic waveform?

- Harmonic waveform is a distortion of the normal Sinewave
- It is characterized by its distortion level
  - For voltage (THD U - Total Harmonic Voltage Distortion)
  - For current (THD I - Total Harmonic Current Distortion)



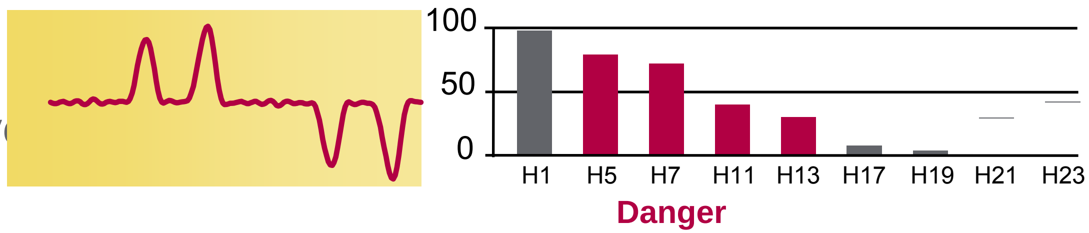
$$\text{THD (U or I) \%} = 100 \times \frac{\sqrt{H_2^2+\ldots+H_n^2}}{H_1}$$

II. Current distortion

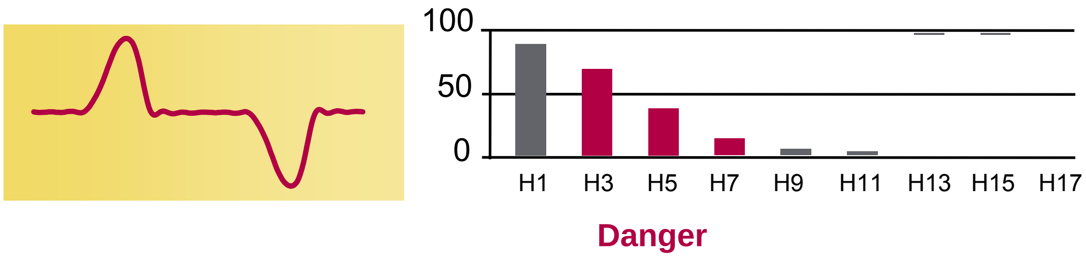
- Waveform examples and harmonic spectrum
  - Three- phase loads

    Variable speed driv

    Lifts…



  - Single-phase loads
    - Computers
    - Phones
    - Lighting ...

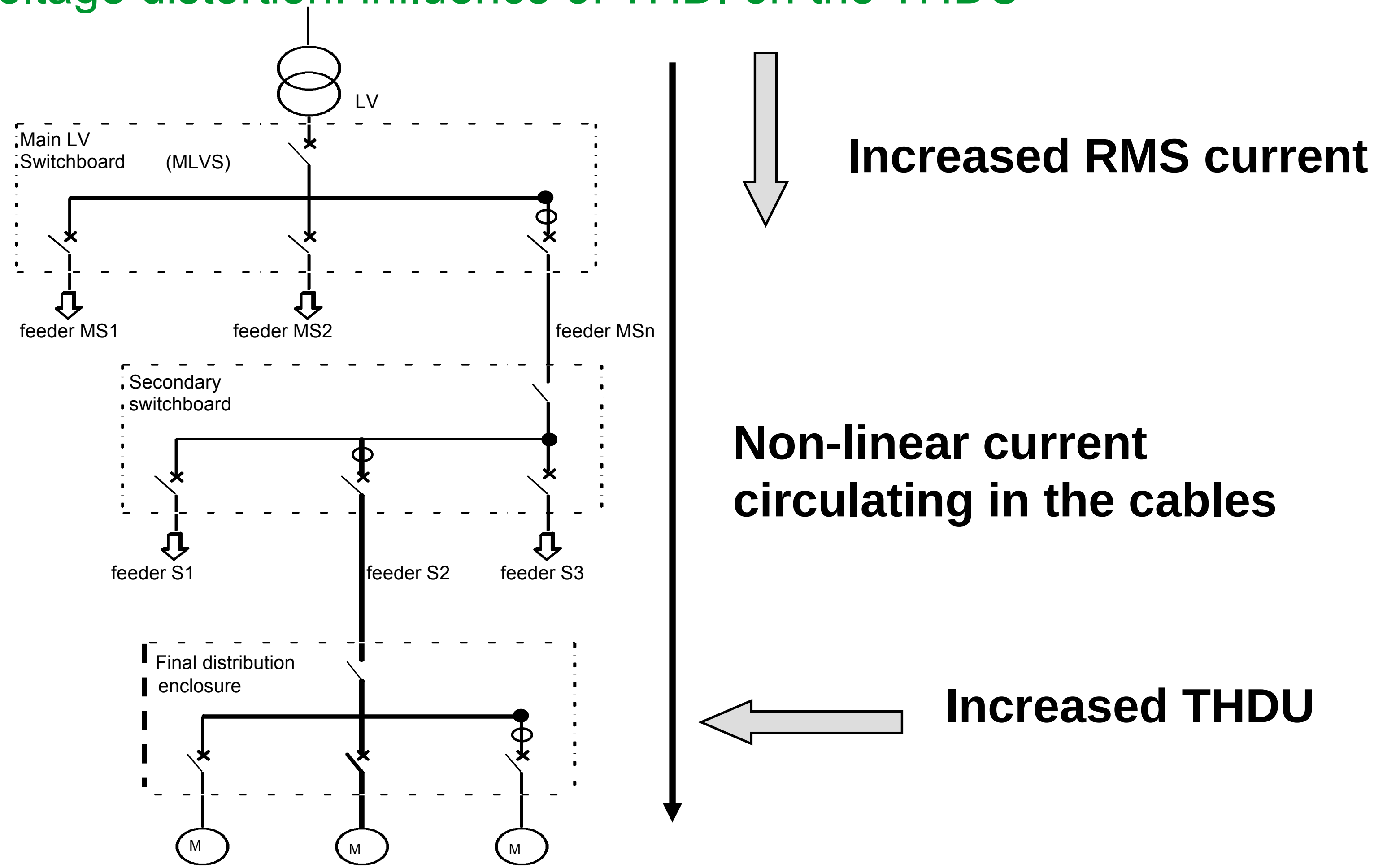


II. The effects of harmonics

- Voltage distortion:
  - Excessive temperature rise in motors
  - Electrical noises
  - Sensitive electronic equipment malfunction
- Increase in the apparent power and over-sizing of sources (UPS, Genset, etc.), capacitors, cables...
  - Derating of electrical equipment or over-sizing
  - Accelerated ageing of equipment
- Flow of current in the neutral conductor and consequently in the PEN:
  - Excessive temperature rise in transformer
  - Tripping of circuit breakers

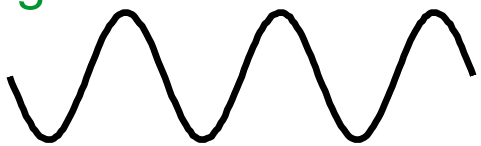
II. The effects of harmonics

- Voltage distortion: influence of THDI on the THDU



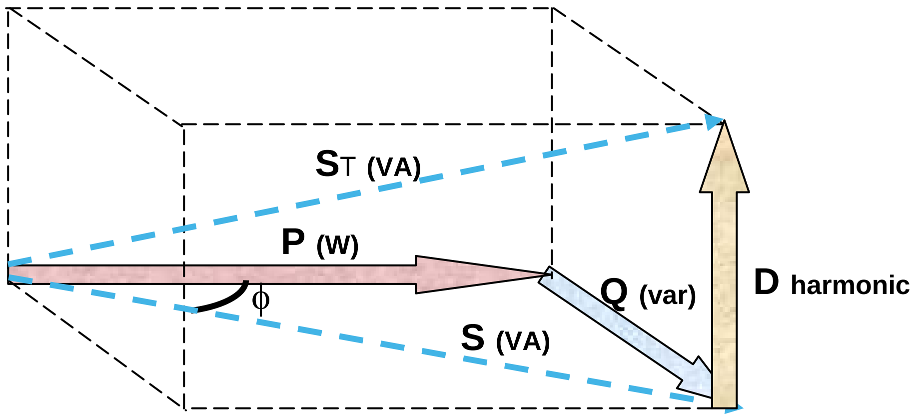
II. The effects of harmonics

- Increase in the apparent power and over-sizing of sources



> Linear load without harmonics:

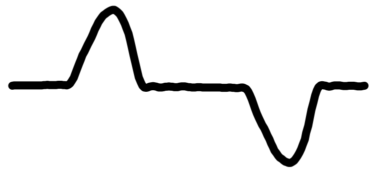
- Cos phi = Power factor = P/S



$$S = \sqrt{P^2 + Q^2}$$

> S = apparent power

$$S = \sqrt{P^2 + Q^2 + D^2}$$

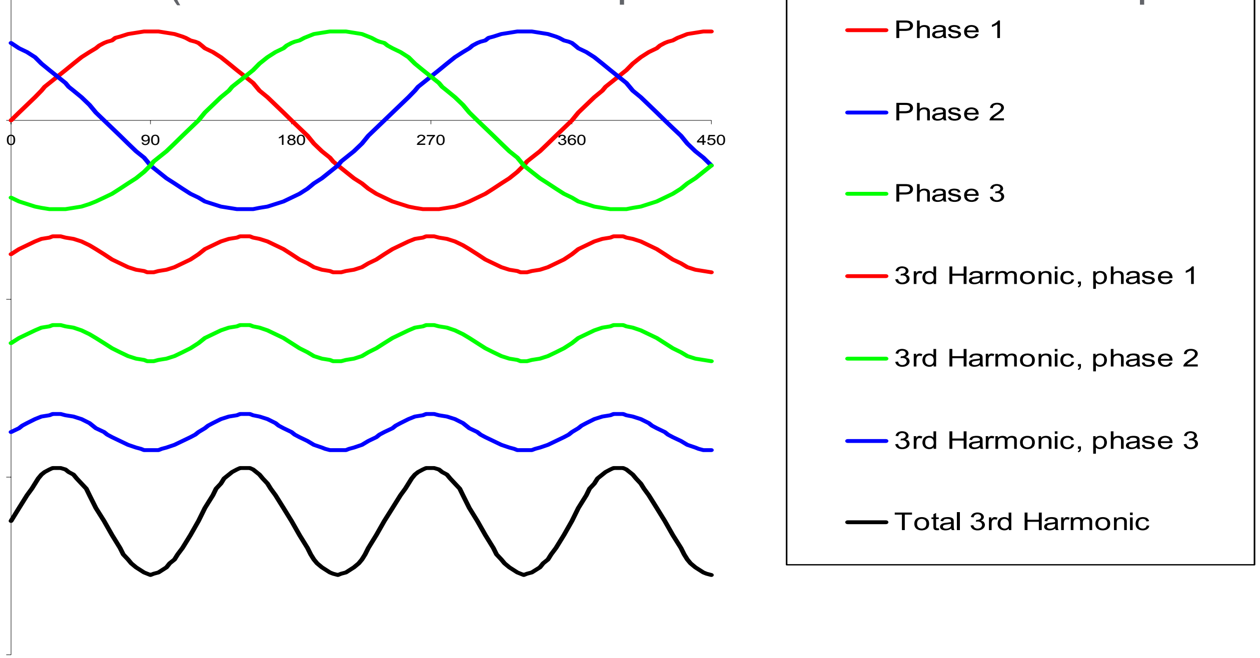


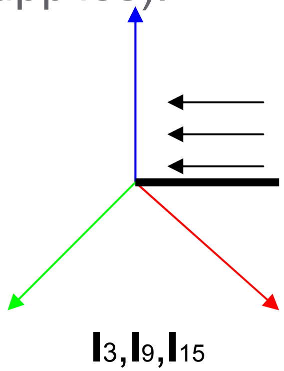
> Non-linear load :

- DPF = Displacement Power Factor - P_1/S_1 (50 Hz fundamental current only)
- True Power factor = P/ST

II. The effects of harmonics

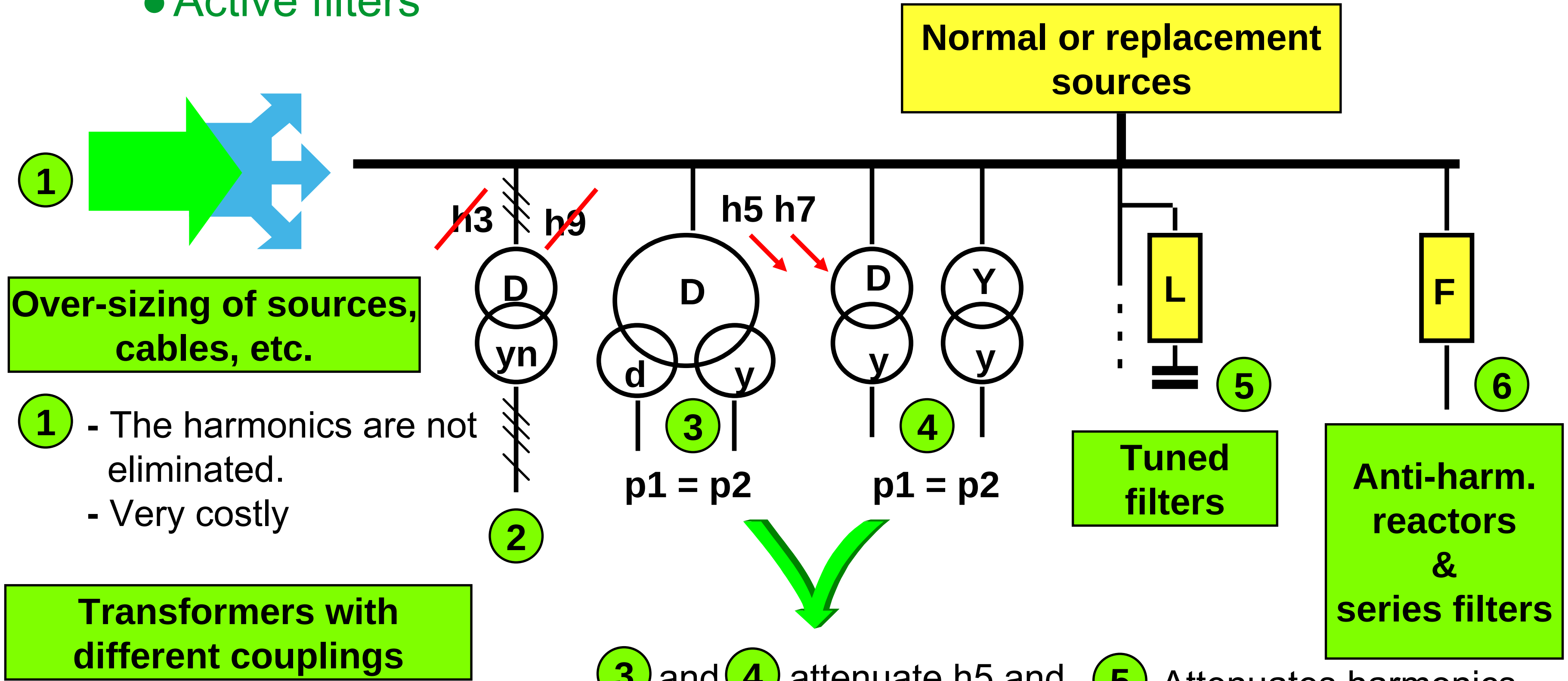
- Flow of current in the neutral conductor
  - The H3 harmonic currents and multiples flow in the neutral conductor.
  - The cross-sectional area of the neutral conductor must be increased (1.7 times that of the phases for switch-mode power supplies).





II. Harmonics mitigation solutions

- Electromechanical solutions
- Active filters



1 - The harmonics are not eliminated.
- Very costly

2 Limits h3 and multiples.

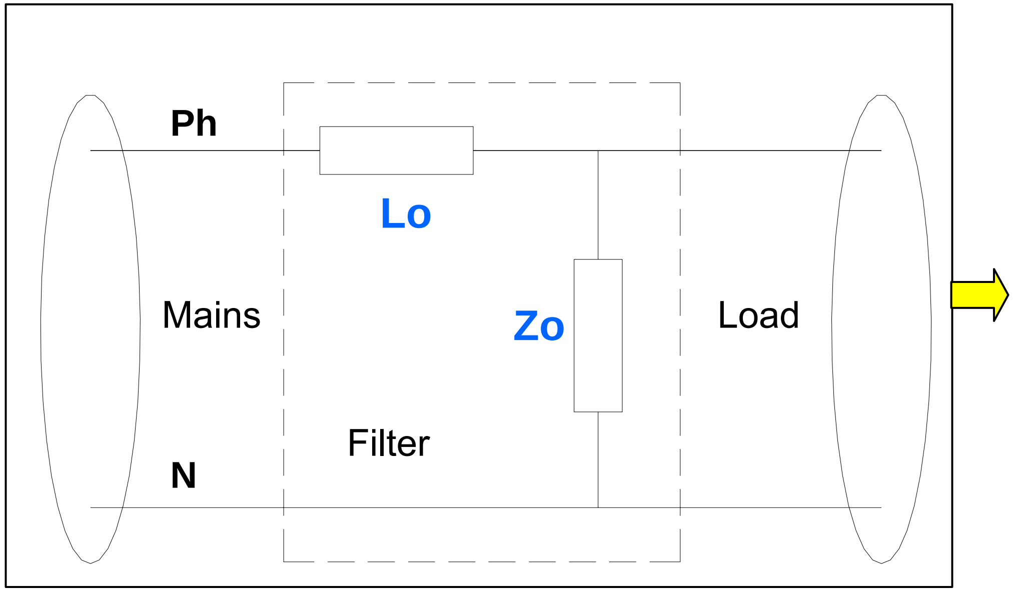
3 and 4 attenuate h5 and h7 (6-pulse bridge)

5 Attenuates harmonics at the tuning frequency.

6 Decreases THD(i).

II. Passive filter: architecture & design

- 3-phase + neutral filter
- Composed of only two elements
  - 1 serial three-phase inductance
  - 1 parallel three-phase inductance



No capacitors

No power electronics

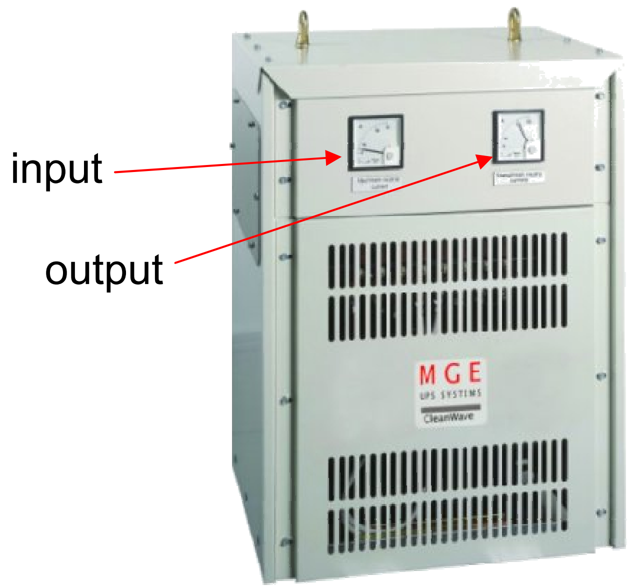
No batteries

No micro controllers

Unmatched reliability, same as that of a dry transformer

II. Cleanwave: solution for neutral currents

- At A Glance:
  - Zero sequence harmonic filter
  - Reduces neutral currents in commercial & industrial buildings
  - Balancing of 3-phase currents
  - 12-280 kVA (expandable)
  - 3-phase low voltage applications



- Customer benefits
  - Simple and highly reliable design
  - Reduction of neutral currents by 10:1
  - Compliance with harmonic standards
  - Capacity upgrade by parallel connection
  - Operational savings
  - Easy integration into power distribution cabinets (Chassis Format)
  - Easy sizing and installer friendly

II. Sizing cleanwave

- CleanWave is designed for the most demanding situations
  - H3 harmonics and multiple: THDI up to 80%
  - Neutral current = 1.8 times phase current

- Very easy sizing

Max power or max. I_{phase} of the load

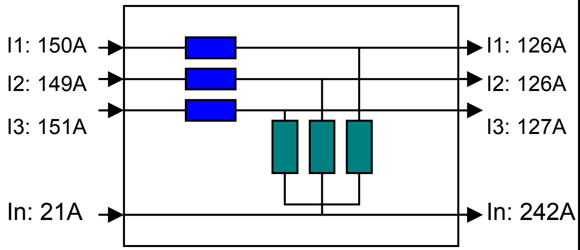
Selection of the filter of immediately higher power or current

25 kVA load

Selection of the 30 kVA CleanWave

II. Unbalanced load tests

Balanced

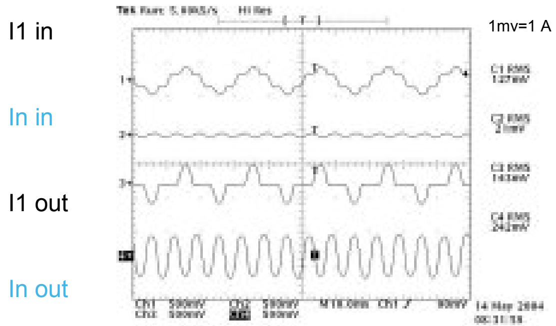


Input:

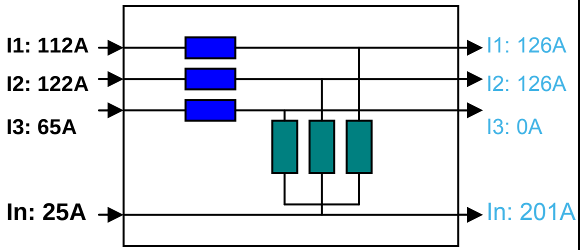
In = 21 A

Output:

In = 242 A



Without Ph3

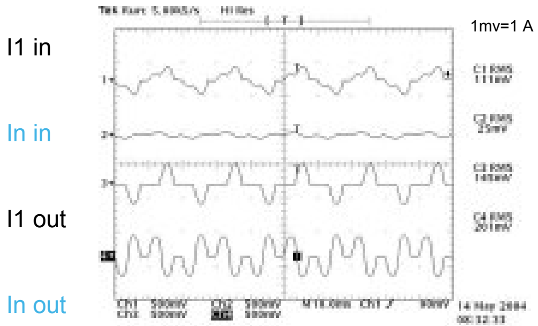


Input:

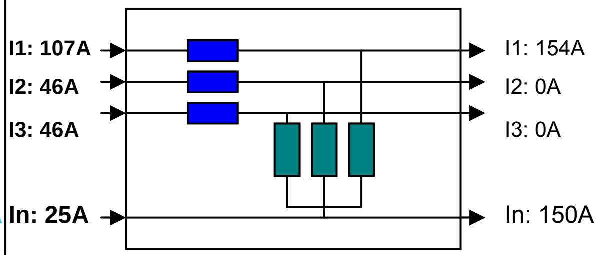
In = 25 A

Output:

In = 201 A



Without Ph2 & 3

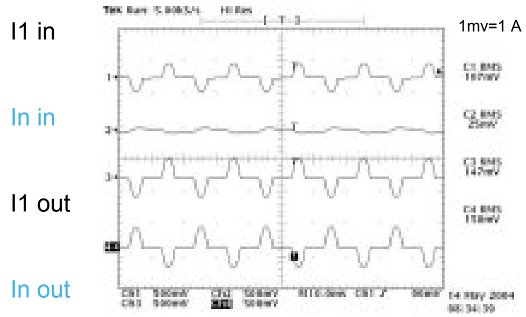


Input:

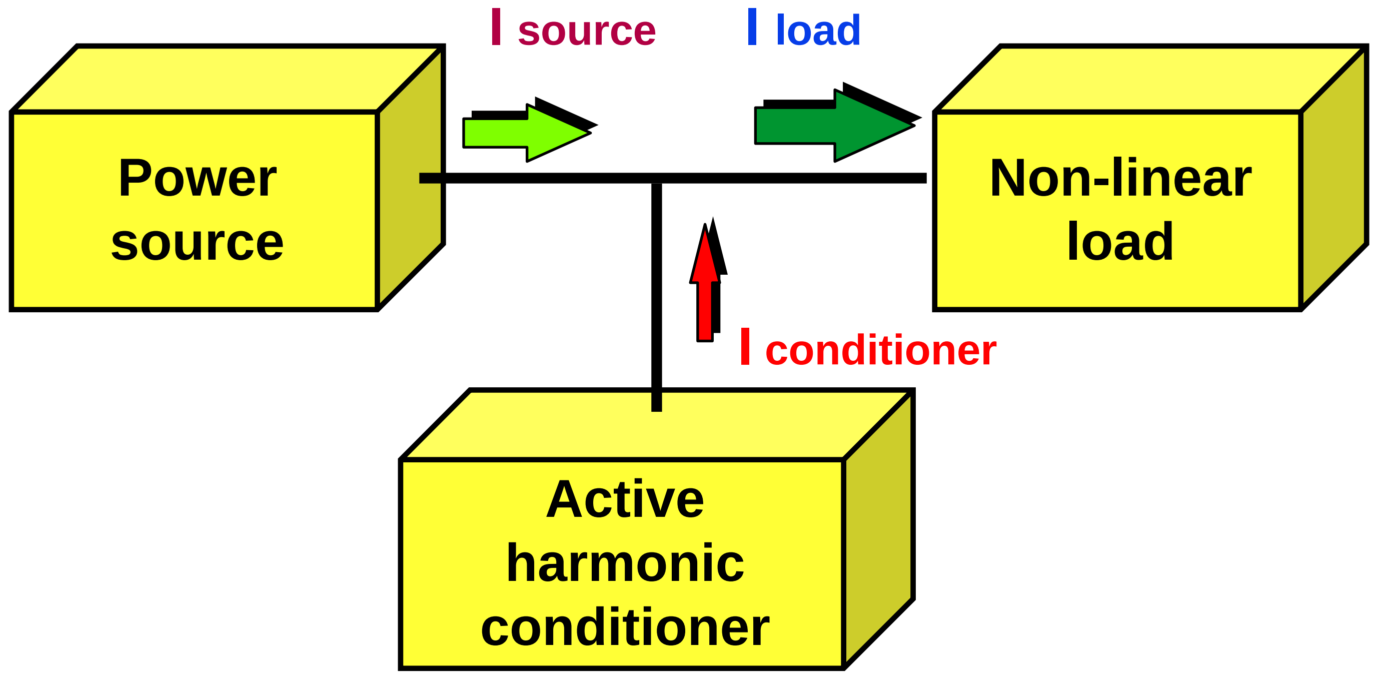
In = 25 A

Output:

In = 150 A



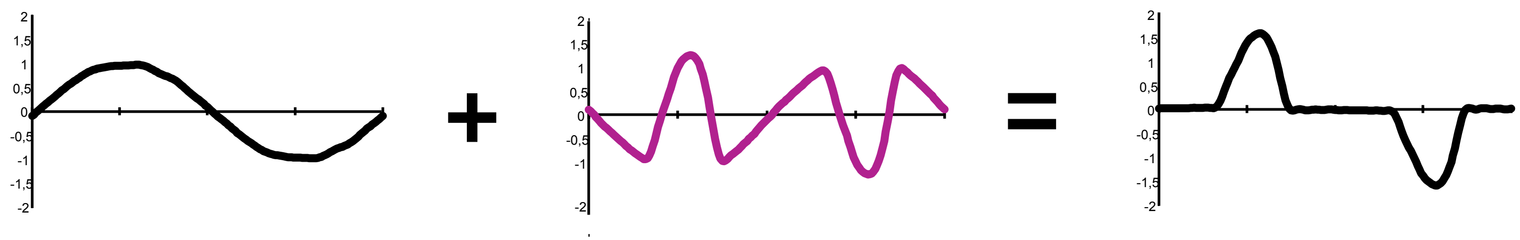
II. Active harmonic conditioner: architecture & design



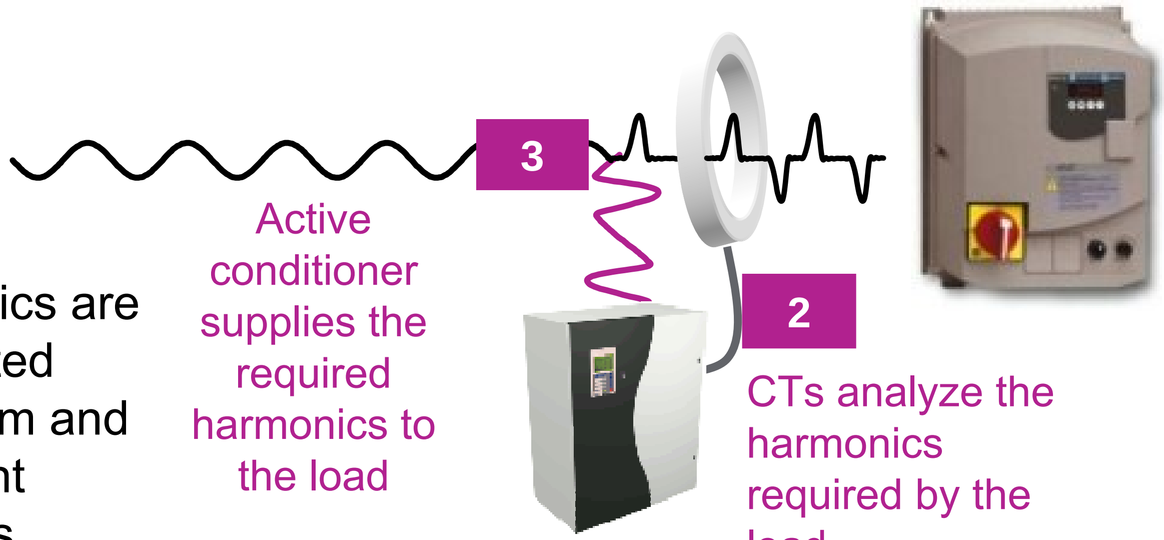
- The active harmonic conditioner generates the harmonic currents required by non-linear loads. These currents are opposite in phase with respect to the current supplied by the source.
- The A.H.C is sized only for harmonic currents
- The current consumed by the load is therefore:

I load = I source + I conditioner

II. Reducing upstream harmonic pollution



I. sinusoidal **I. conditioner** **I. load**



4 The harmonics are eliminated upstream and apparent power is reduced

Active conditioner supplies the required harmonics to the load

3

2 CTs analyze the harmonics required by the load

1 Equipment is the source of harmonics

II. Sinewave standard solution: 20-480A of harmonic compensation

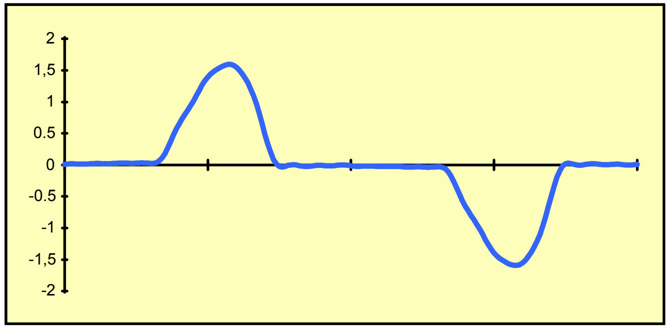
- SineWave includes everything for a simple and functional basic solution:
  - EMC filter to comply with EN55011 level A and IEC 1000-4
  - 7-language user interface
  - Diagnostic and maintenance menu
  - Basic indications by 3 LEDs
  - Relay contacts for remote indications
  - Terminal blocks for power and sensor connections
  - Wide choice of current transformers: split or closed

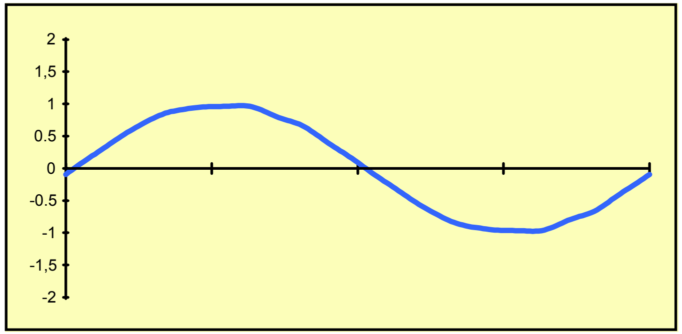
II. Sinewave features

- Input
  - Voltage : 400 V , - 20% , + 15%
  - Phases : 3-phase with or without neutral. Compatible Operation with single phase and unbalanced load
  - Frequency : 50 Hz or 60 Hz, +/- 8% auto-sensing

- Compensation characteristics
  - Harmonics covered : H 2 to H 25
  - Type of compensation : Harmonics - cos phi - mixed (Hn + cos)
  - Compensation mode : Overall or selective (specific harmonics)
  - Attenuation ratio : >10 at full load (THDI)
  - Cos phi correction : Up to 1
  - THDU reduction : According to the installation parameters, THDU reduction will be determinated by the SITE AUDIT
  - Response time : < 40 ms in overall current compensation mode
  - Overload : Automatic current limitation

II. Example: Variable Speed Drive load

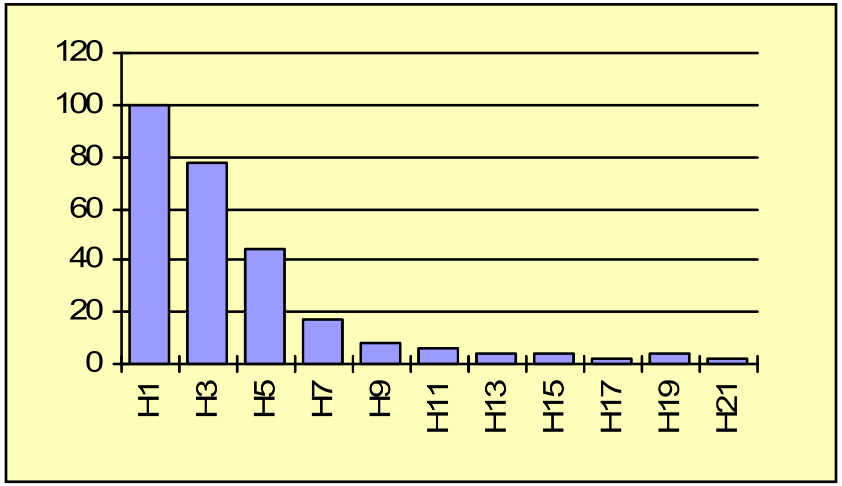




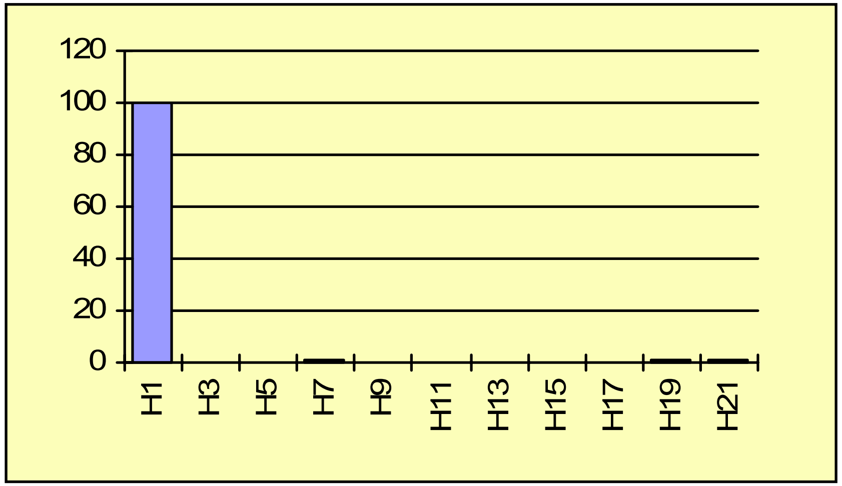
Mains current without active conditioner		Mains current with active conditioner	
I phase	**= 48 A**	**I phase**	**= 38A (-21%)**
THDI	**= 81%**	**THDI** (reduced by a factor of 24)	**= 3.4%**
I neutral	**= 42 A**	**I neutral**	**= 2.6 A**
S	**= 10.6 kVA**	**S**	**= 8.4 kVA**
Power factor	**= 0.77**	**Power factor**	**= 1**
Cos phi 1	**= 0.99**	**Cos phi 1**	**= 1**

II. Example: Variable Speed Drive load

Test Results of a 60 A Active Conditioner



Harmonic current without SineWave



Harmonic current with SineWave

THDI = 92.6%

PF = 0.73

Reduction of 27% in the line RMS current

II. Accusine solution

- Robust design suitable for heavy industrial applications
- IP54 protection enclosure is standard
- Full EMC compliance with 89/336EEC, conforms to IEC/EN 60439-1, EN61000-6-4 class A, EN61000-6-2 standards
- Current output ratings of 50 A, 100 A or 300 A
- Can be paralleled up to 10 units in any rating combination
- Ultra fast response time (1/2 cycle)
- Cancel harmonic up to 50th order
- ABS Certified for Marine applications

II. Accusine features

- Input
  - Voltage : 208-480V, - 10% , + 10%; auto sensing
  - Phases : 3-phase, 3-wire with or without neutral. Compatible Operation with single phase and unbalanced load
  - Frequency : 50 Hz or 60 Hz, +/- 5% auto-sensing

- Compensation characteristics
  - Harmonics covered : H 2 to H 50 (no filtering on neutral conductor)
  - Type of compensation : Harmonics - cos phi - mixed (Hn + cos)
  - Compensation mode : overall
  - Attenuation ratio : 10:1 overall
  - Cos phi correction : Up to unity; can also inject lagging VARS
  - THDU reduction : Guaranteed compliance with IEEE519; UK G5/4 or IEC 61000-2-3
  - Response time : < 10 ms
  - Overload : Automatic current limitation

II. Customer benefits / active power solutions

- Safe and reliable AC electrical distribution systems
  - Overloading and overheating of the neutral conductor cancelled
  - Nuisance tripping of protection circuit breakers avoided
- Improved power quality
  - Reduction of the THD(V)
  - Cancellation of the voltage potential on the neutral conductor
- Increased lifetime of AC distribution system equipment
- Over-sizing cables, transformers and other AC distribution equipment avoided
- Compliance of installations with harmonic standards ensured
- Improved power factor
- Lower energy expenses/bills

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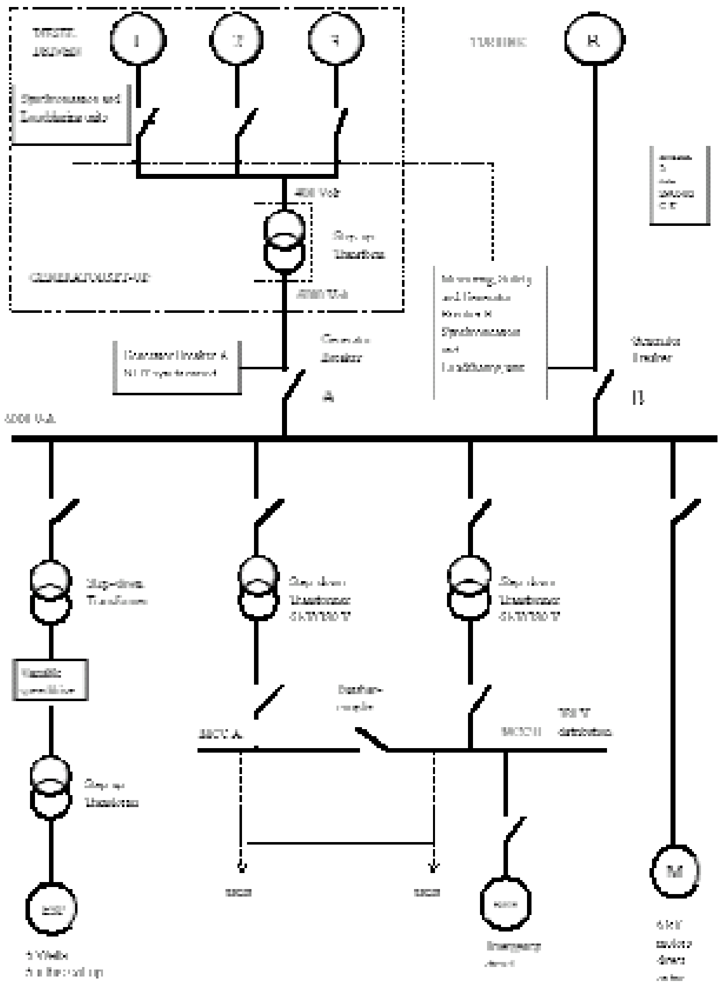
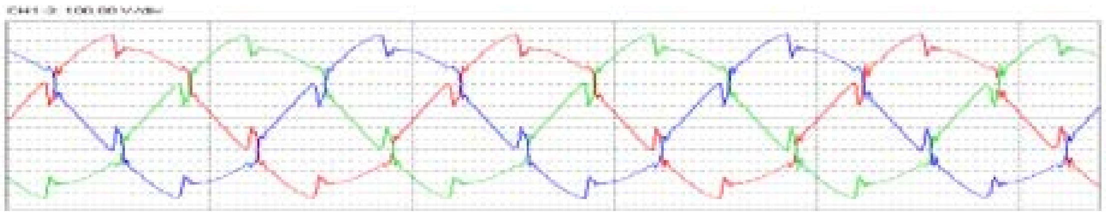
III. Accusine application case study

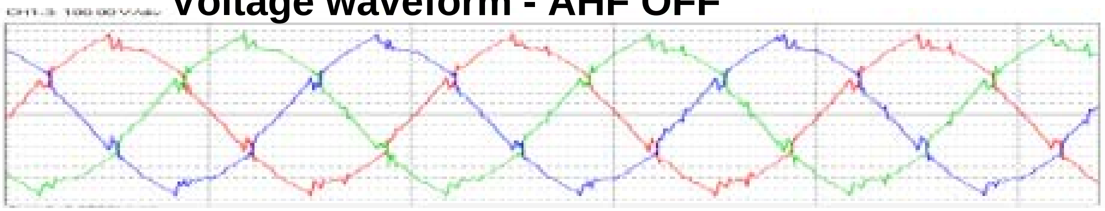


- Oil platform in the North Sea with turbine / diesel generators feeding 6 KV network
  - Mechanical resonance on the platform when pump VFDs operated above 49 Hz due to generator loading
  - Each 1 Hz increment in pump speed equals $6k/day incremental revenue per pump (2003 prices)
- 2 x 600 KW VFDs at 380V
  - 300A AHF for each VFD
  - Operating in harmonic + power factor correction mode
  - Increased pump speed by 1 Hz

III. Accusine application case study

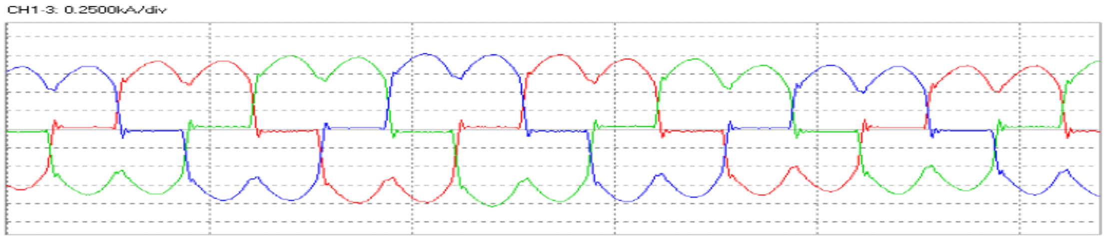


Voltage waveform - AHF OFF

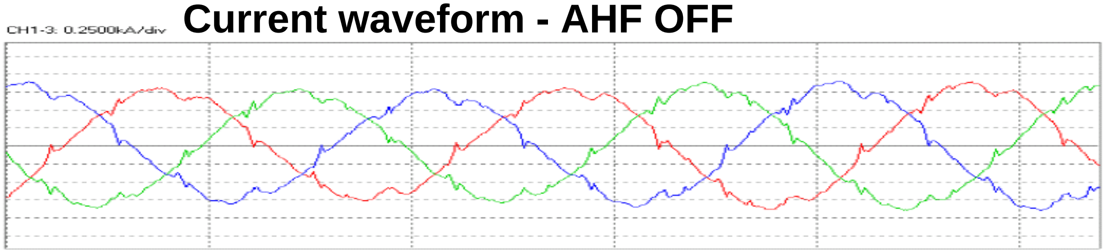


Voltage waveform - AHF ON

- THD(V) reduced from 12.6% to 6.0%
- Note high voltage notching & distortion on generator fed network



Current waveform - AHF OFF



Current waveform - AHF ON

- THD(I) reduced from 31.8% to 7.2%
- PF from 80.3% to 95.2%

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IV. Conclusion

- Power quality issues are well worth some consideration,

- Even more so for Oil & Gas processes where the availability and quality of Power is quite critical,

- Correct identification of the root causes of the problem is essential to choosing and implementing the best solution right from the start => Talk to the experts.

The 3 main messages

- Schneider Electric is your Power Quality expert
- We offer a variety of solutions and products to help identify and correct power quality problems
- Investing in power quality will improve both your operations and profits