


Power Quality Measurements and Solutions from “Circutor”

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BDM – Technical



Mission



“To develop the **innovation** and **technology** in order to offer **total solutions** to the market”

Power Quality Indices

Index	Definition	Main applications
Total harmonic distortion (THD)	$\left(\sqrt{\sum_{i=2}^{\infty} I_i^2} \right) / I_1$	General purpose; standards
Power factor (PF)	$P_{tot} / (V_{rms} I_{rms})$	Potentially in revenue metering
Telephone influence factor	$\left(\sqrt{\sum_{i=2}^{\infty} w_i^2 I_i^2} \right) / I_{rms}$	Audio circuit interference
C message index	$\left(\sqrt{\sum_{i=2}^{\infty} c_i^2 I_i^2} \right) / I_{rms}$	Communications interference
IT product	$\sqrt{\sum_{i=1}^{\infty} w_i^2 I_i^2}$	Audio circuit interference; shunt capacitor stress
VT product	$\sqrt{\sum_{i=1}^{\infty} w_i^2 V_i^2}$	Voltage distortion index
K factor	$\left(\sum_{k=1}^{\infty} k^2 I_k^2 \right) / \sum_{k=1}^{\infty} I_k^2$	Transformer derating
Crest factor	V_{peak} / V_{rms}	Dielectric stress
Unbalance factor	$ V_- / V_+ $	Three phase circuit balance
Flicker factor	$\Delta V / V $	Incandescent lamp operation; bus voltage regulation; sufficiency of short circuit capacity

Cost of Power Quality

Calculated by the sum of the cost of the measures taken to improve PQ **or** the cost of customer lost in industrial production **or** the payment to customers for PQ problems **or** the total active energy loss plus metering error plus loss of life plus cost to serve peak demand including harmonic loss?

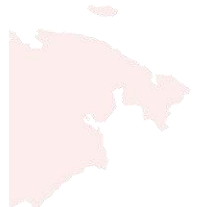
Cost of Power Quality

1. Power quality indices / pitfalls / three phase phenomena and applications / 'interharmonics' and other non-harmonics
2. Power acceptability, when is electric power delivered 'acceptable', vulnerability of loads
3. Series voltage boost hardware
4. Rectifier loads
5. Power quality standards
6. Why is power quality important? The salability of power quality

To Overcome the Power Quality Issues...

- To Improve anything before you must control it
- To control anything before you must measure it
- To Measure anything , before you must **measure it**

Measuring and Control



POWER ANALYZERS

CVM Analyzers

CVMk2: Network and Power quality analyzer

Equipment to be mounted in LV general panel, to be connected either LV or MV. Modular equipment with possible extensions. (3 slots) throughout I/O digital cards, I/O analogical cards, Ethernet.



CVM-NRG96: Power analyzer

Equipment to be mounted in LV big panels. Panel assembly 96x96. More than 250 electrical parameters. RS 485 Communication port with Modbus/RTU protocol.



CVM-Mini: Power analyzer

Equipment to be mounted in LV modular panels. Din rail assembly, 3 moduls. More than 250 electrical parameters. RS 485 Communication port with Modbus/RTU protocol. The smaller analyzer available in the market



POWER ANALYZERS

CVM-1D



- Single phase analyzer
- RS485 Modbus/RTU communication.
- 1 Digital Output NPN
- Electrical parameters:
 - Voltage
 - Current
 - Active and Apparent Power
 - Reactive Power (kVArL / kVArC)
 - Active and Reactive Energy
 - Power Factor
- 4 Quadrants Device

POWER ANALYZERS

CVM-NRG96

CVM-NRG96 is a power panel meter that measures, calculates and displays main electric parameters for balanced or unbalanced three-phase networks.



CVM-NRG96 is compact and small-sized instrument.

Due to its minimum depth, the CVM-NRG96 is an ideal complement for most electric panels where the “space” is determinant factor.

Power analyzer of networks of 4 quadrants.

Illuminated Display LCD of 4 lines .

Modbus communication

POWER ANALYZERS



CVM-MINI

ITF-LONWORKS-C2

3 Modules in DIN Rail.

Possibility of measurement in Medium and Low Voltage.

Balanced or unbalanced three-phase networks in true effective value.

More than 50 electrical parameters through LonWorks communication.

SNVT (Standard Network Variables Types).

Current by means of external transformer $\dots/5$ A. or $\dots/1$ A

Assembly in panel 72x72 mm with frontal adapter .

2 Digital Outputs.

Universal Power Supply.

Sealable.



POWER ANALYZERS

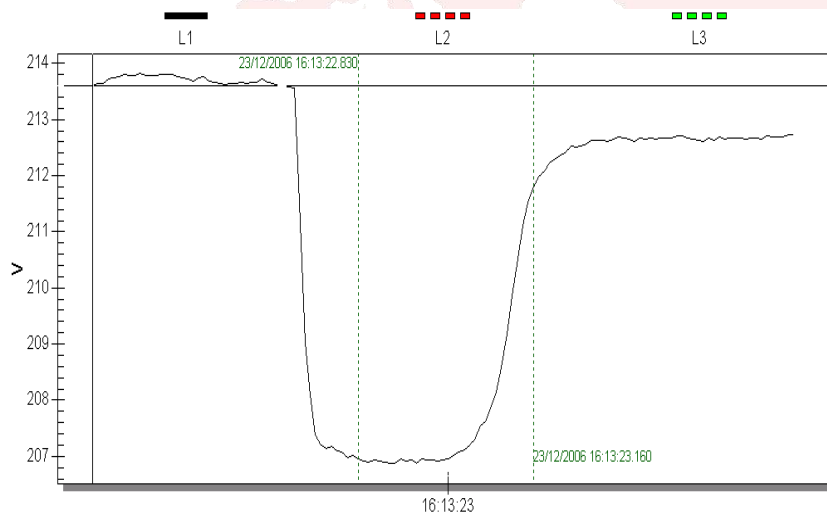
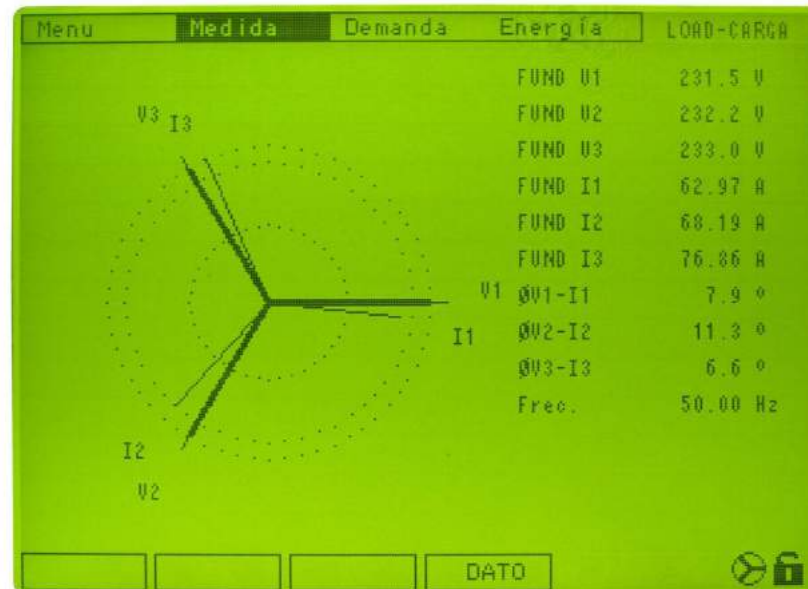
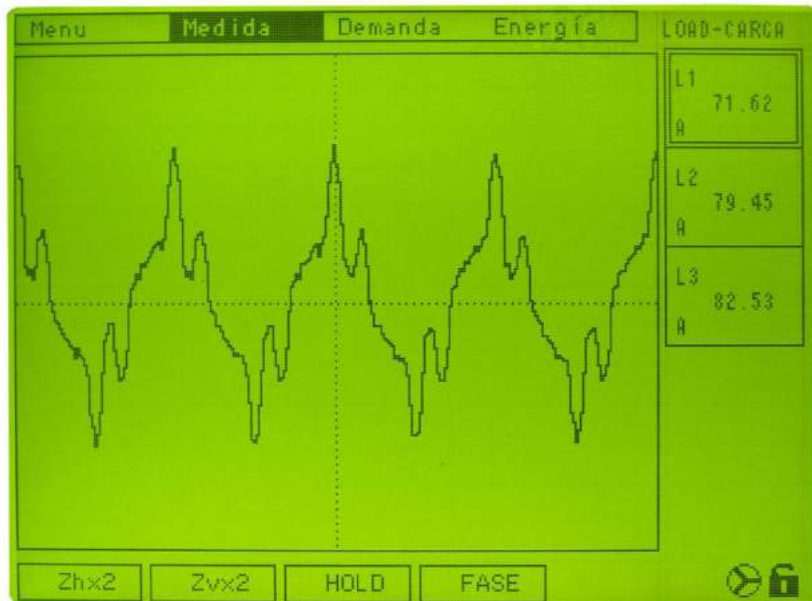
CVMk2

Features:



✓ Power and Precision

- Class 0.2 or 0.5 in Power and Energy
- Harmonic Spectrum / Waveforms
- Sag/swells/interruptions
- For the most demanding customer.



• Quality

- Voltage events register
- Evaluation EN50160.
- STD Register file
- Flicker Assessment
- Unbalance Calculation, kd
- Asymmetry calculation, ka
- Evaluation factor K

CURRENT TRANSFORMERS

MC1 - MC3

Efficient transformers
"Small units, top performance"
Built-in current measurement system

 MC3 system



NEW



Portable Analyzers

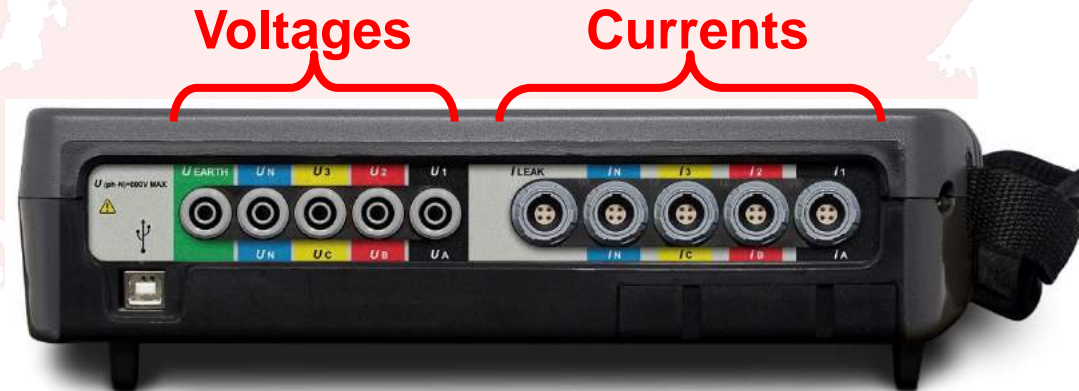


AR6



Portable Analyzers

- **5** voltage inputs to measure phases, neutral and ground voltage.
- **5** current inputs to measure phases, neutral and leak current.



- More than 500 electrical parameters.
- High resolution 5,7" colour graph screen
- Friendly use.




VGA
display



PowerVision+

Portable Analyzers

- 128 samples by cycle of 10 channels
- Class 0,5
- Internal clock for maximums and minimums values
- Photo captures. 
- Colors, measures and intallations customized



Language:

Time to switch off display: minutes

Time to lock keyboard: minutes

Password:

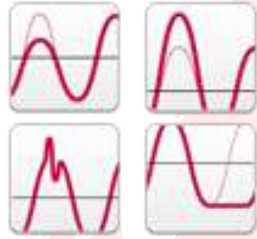
Phase colors:

L1 L2 L3 LN LK

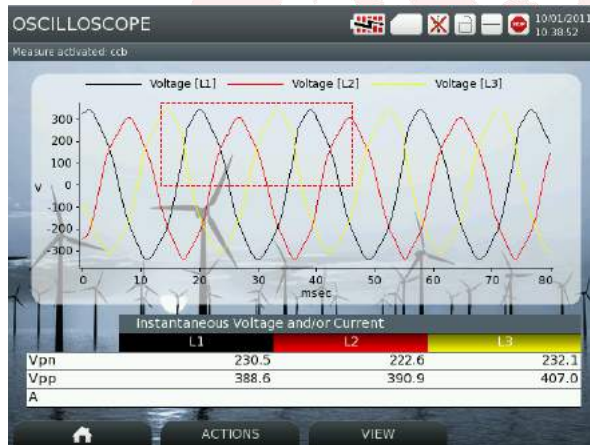
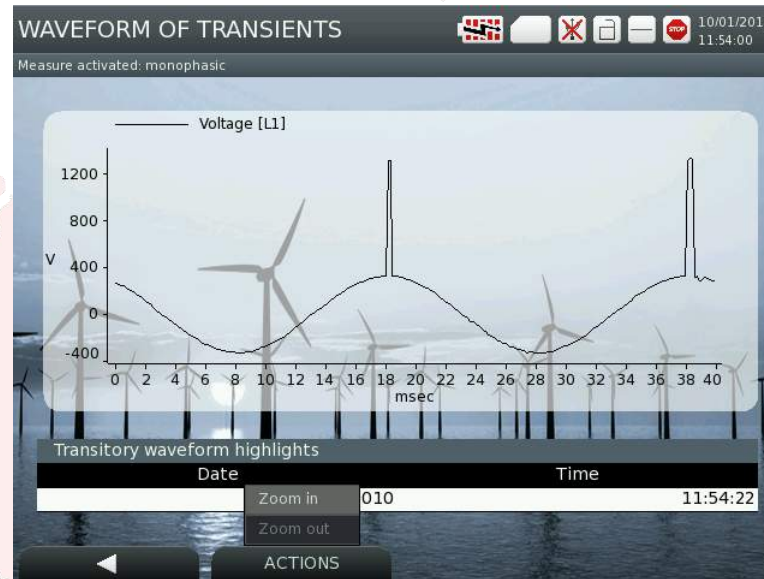
Background:

Portable Analyzers

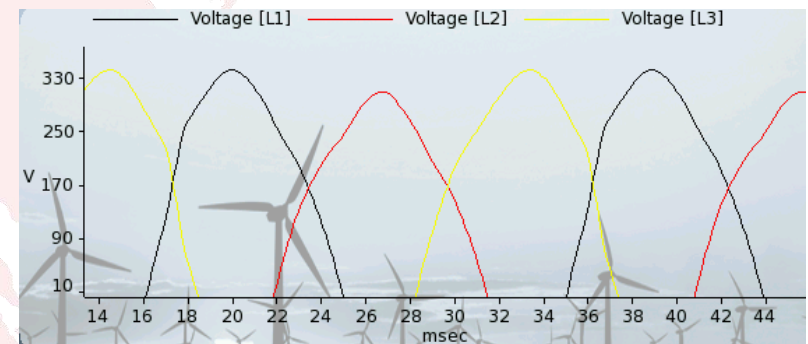
- Transients.



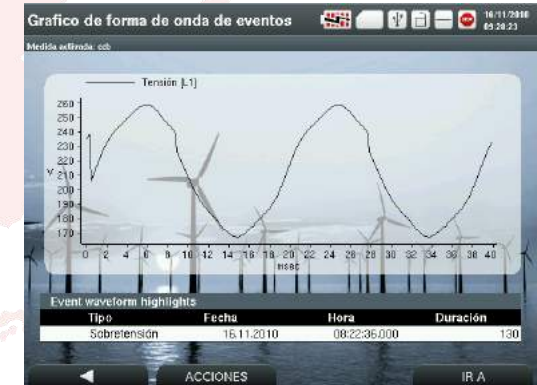
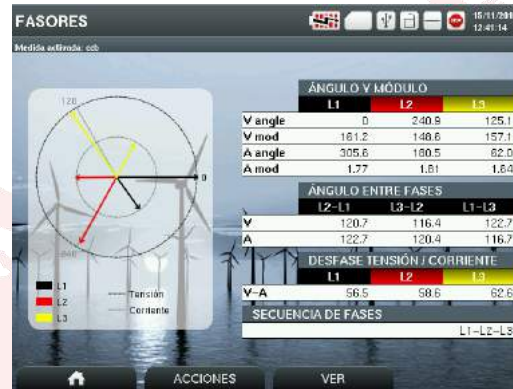
- Waveforms



Zoom



Portable Analyzers



Fundamental Measures

- RMS Values:

$$I_{RMS} = \sqrt{\sum_{1}^n I_d^2}$$

$$V_{RMS} = \sqrt{\sum_{1}^n V_b^2}$$

- Individual Distorsion:

$$I_n(\%) = \frac{I_n}{I_1} \cdot 100$$

$$V_n(\%) = \frac{V_n}{V_1} \cdot 100$$

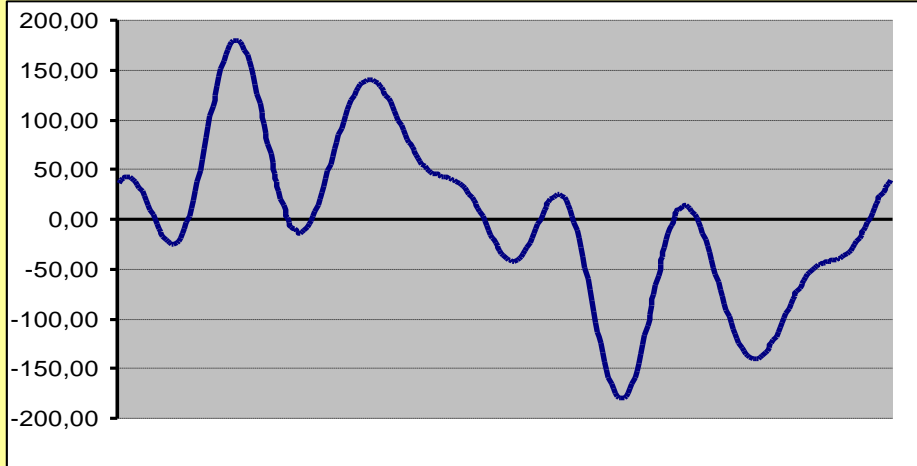
- Total Harmonic Distorsion:

$$THDI(\%) = \frac{\sqrt{\sum_{2}^{40} I_n^2}}{I_1} \cdot 100$$

$$THVDI(\%) = \frac{\sqrt{\sum_{2}^{40} V_n^2}}{V_1} \cdot 100$$

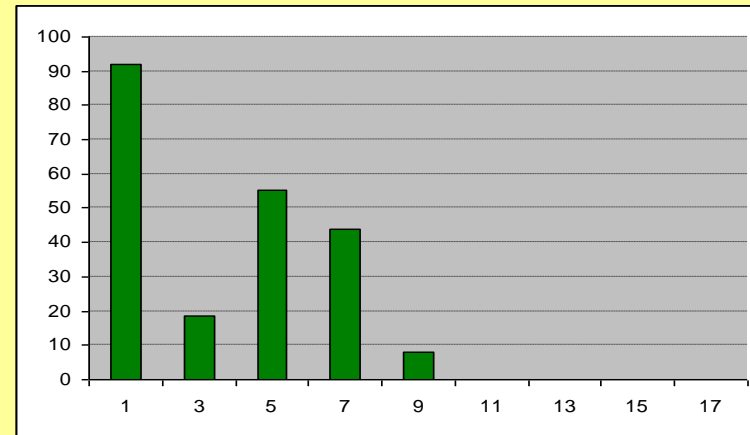
Example of Fundamental Measures

I1=65A; I3=13A; I5=39A; I7=31A; I9=2A



**WAVE
SHAPE**

SPECTRUM 



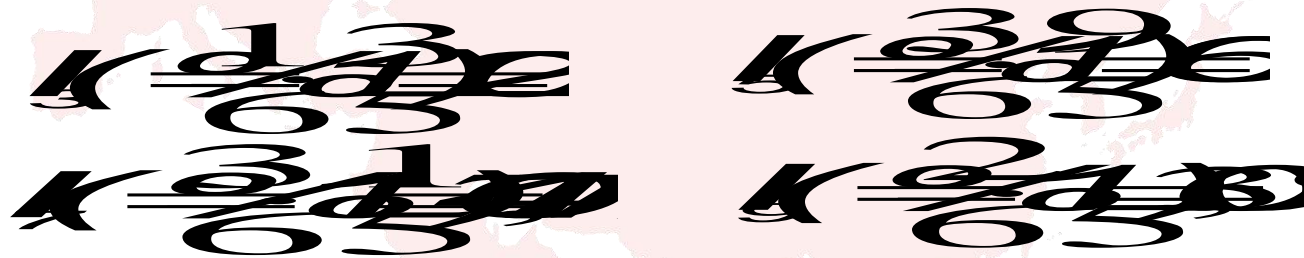
Example of Fundamental Measures

$I_1=65A; I_3=13A; I_5=39A; I_7=31A; I_9=2A$

- RMS Values:



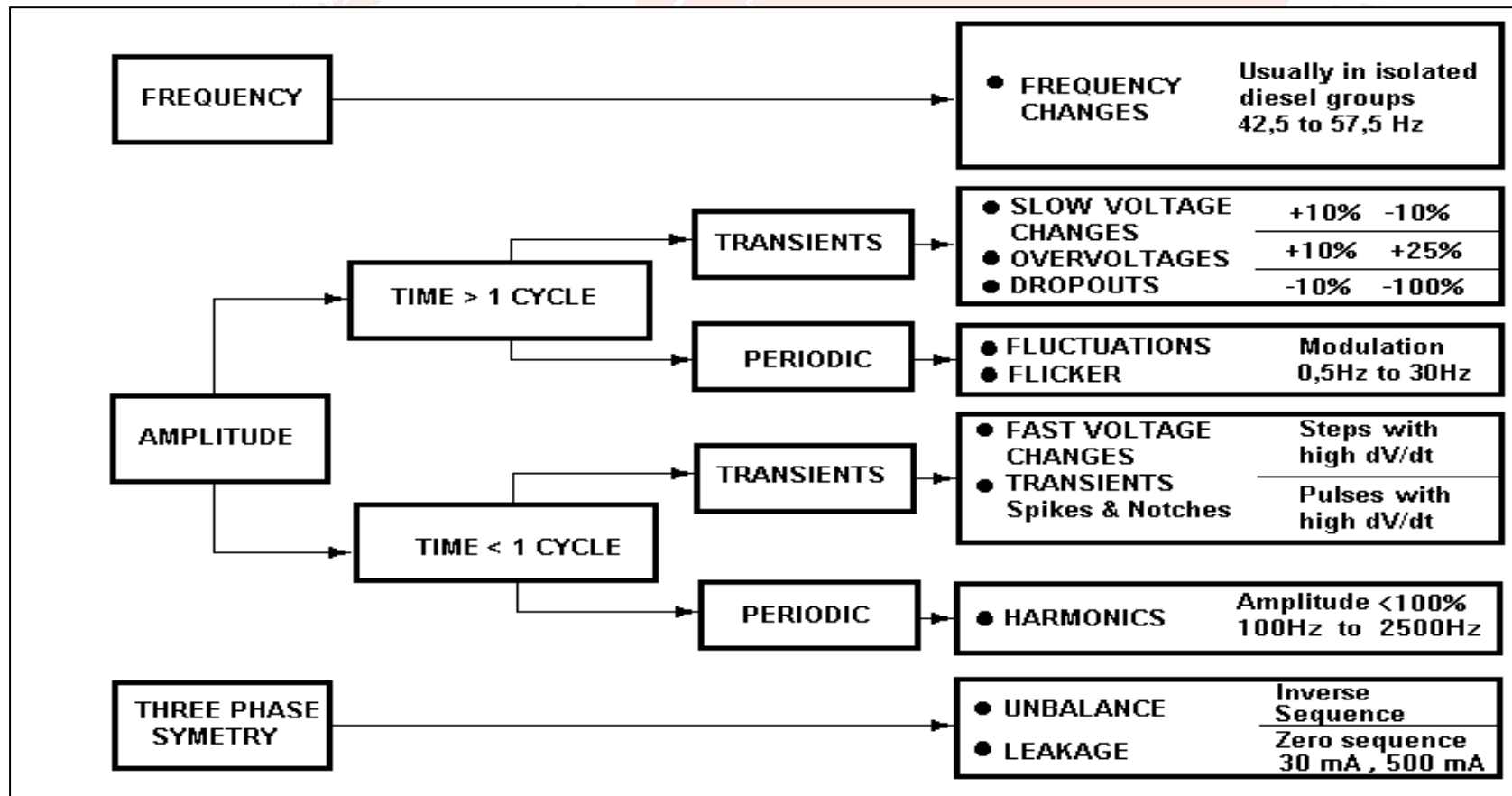
- Individual Distorsion:



- Total Harmonic Distorsion:



What is the effect of harmonics?



Harmonic Effects

• Wires

- Increase of RMS current, so increase losses by Joules effect.

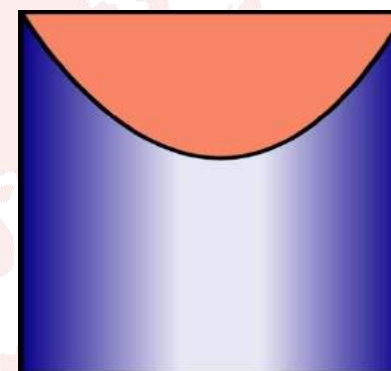
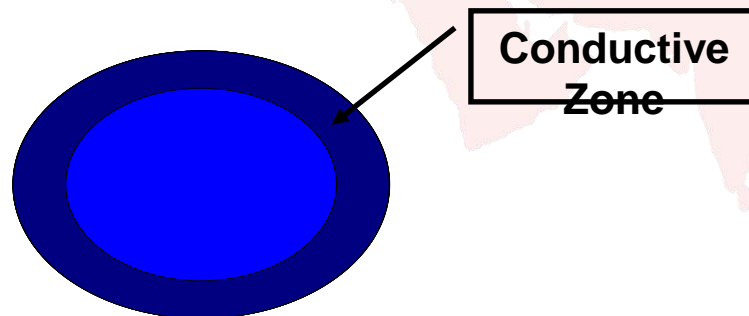


Effects

- Trip of protections
- Overheating the cable

- Increase of R with the frequency

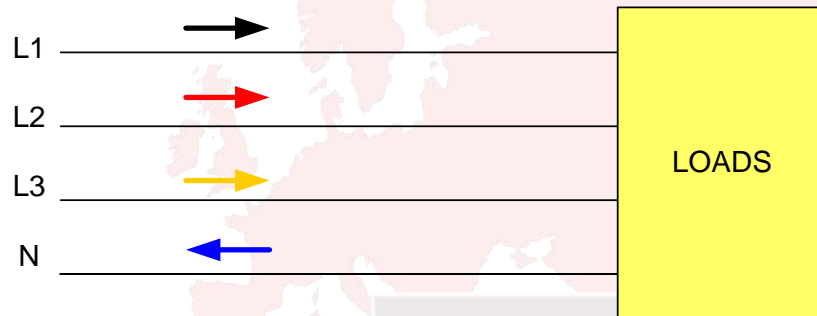
- “Skin effect”



Harmonic Effects

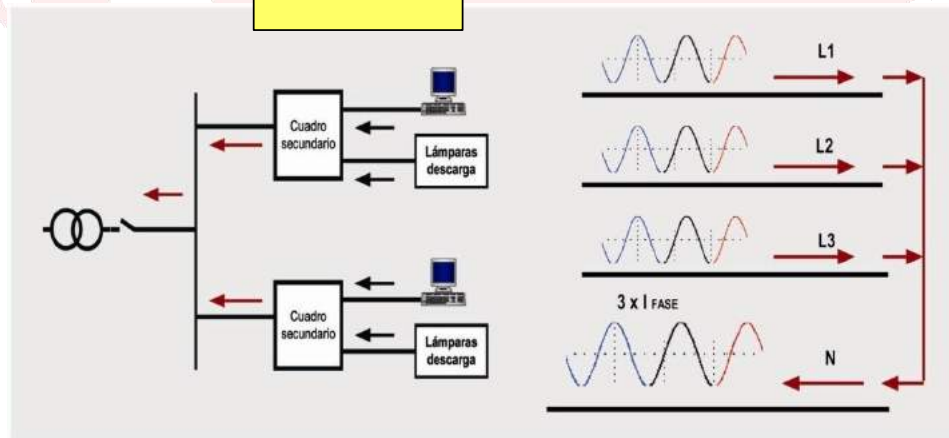
• Neutral Wire

❑ Return of homopolar current through neutral



Effects

- Trip of protections.
- Overheating of neutral wire.
- Overcurrent through neutral.
- Voltage neutral-earth.



Power Quality measurements and Solutions

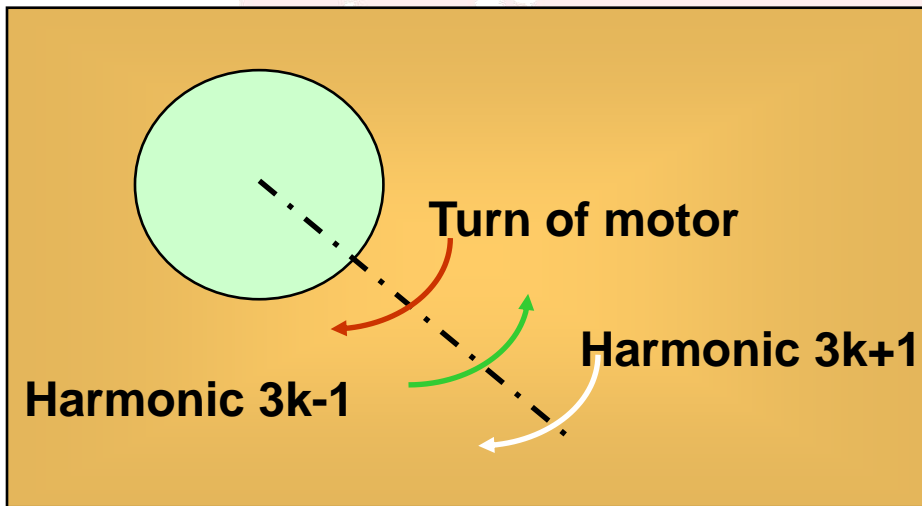
Harmonic Effects

Motor

- ❑ Increase Joule's effect losses.
- ❑ Increase magnetic losses.
- ❑ Efficiency of motor

Effects

- Overheating of winding.
- Increase magnetic losses.
- Efficiency of motor
- Reduction of torque.
- Vibration, oscillation



SEQUENCE

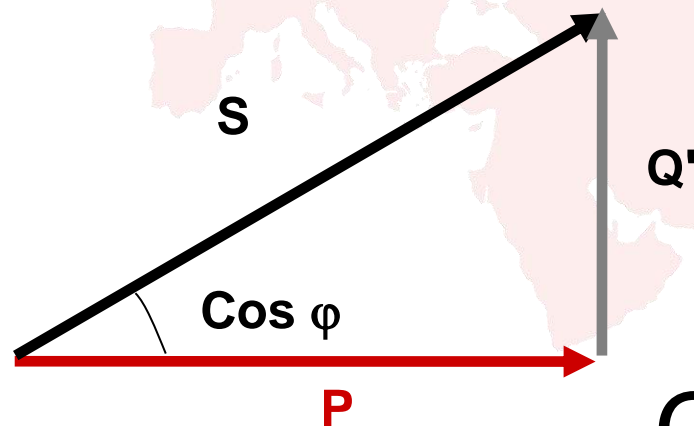
1	2	3	4	5	6
+	-	0	+	-	0

Harmonic Effects

• Power Factor

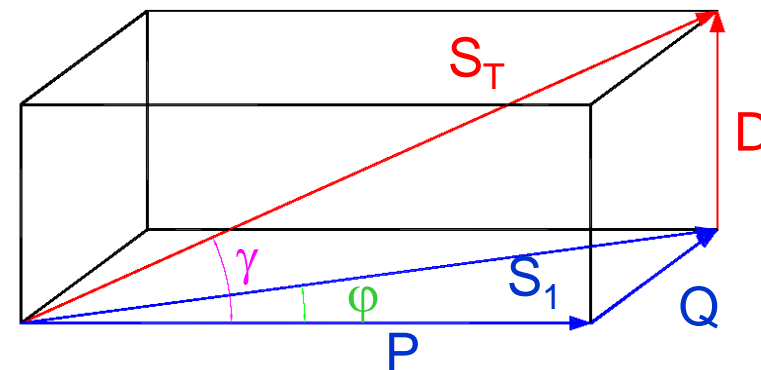
□ Without harmonics:

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



□ With harmonics:

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



$\cos \phi \neq PF$

Harmonic Effects

• Power Factor (Example)

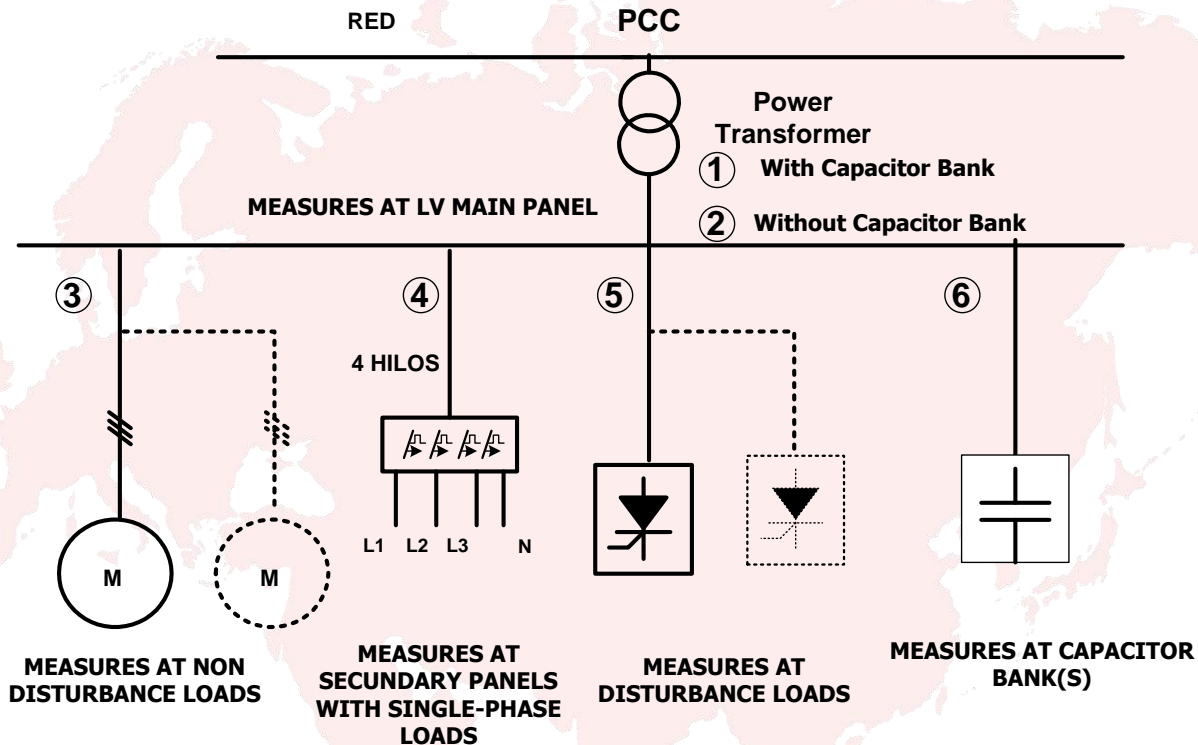
P = 400 kW ; Q = 192 Kvar ; THDI% = 48%

$$PF = \frac{P}{S} = \frac{400}{496} = 0.806$$

$$PF = \frac{1}{\sqrt{1 + THD^2}} = \frac{1}{\sqrt{1 + 0.48^2}} = 0.806$$

$$PF_{Dist} = \frac{P}{\sqrt{P^2 + Q^2}} = \frac{400}{\sqrt{400^2 + 192^2}} = 0.806$$

Previous Information



S_n (Power of Transformer):	kVA
U_2 (Rated Voltage):	V
U_{cc} (Short-Circuit Voltage):	%

Measures

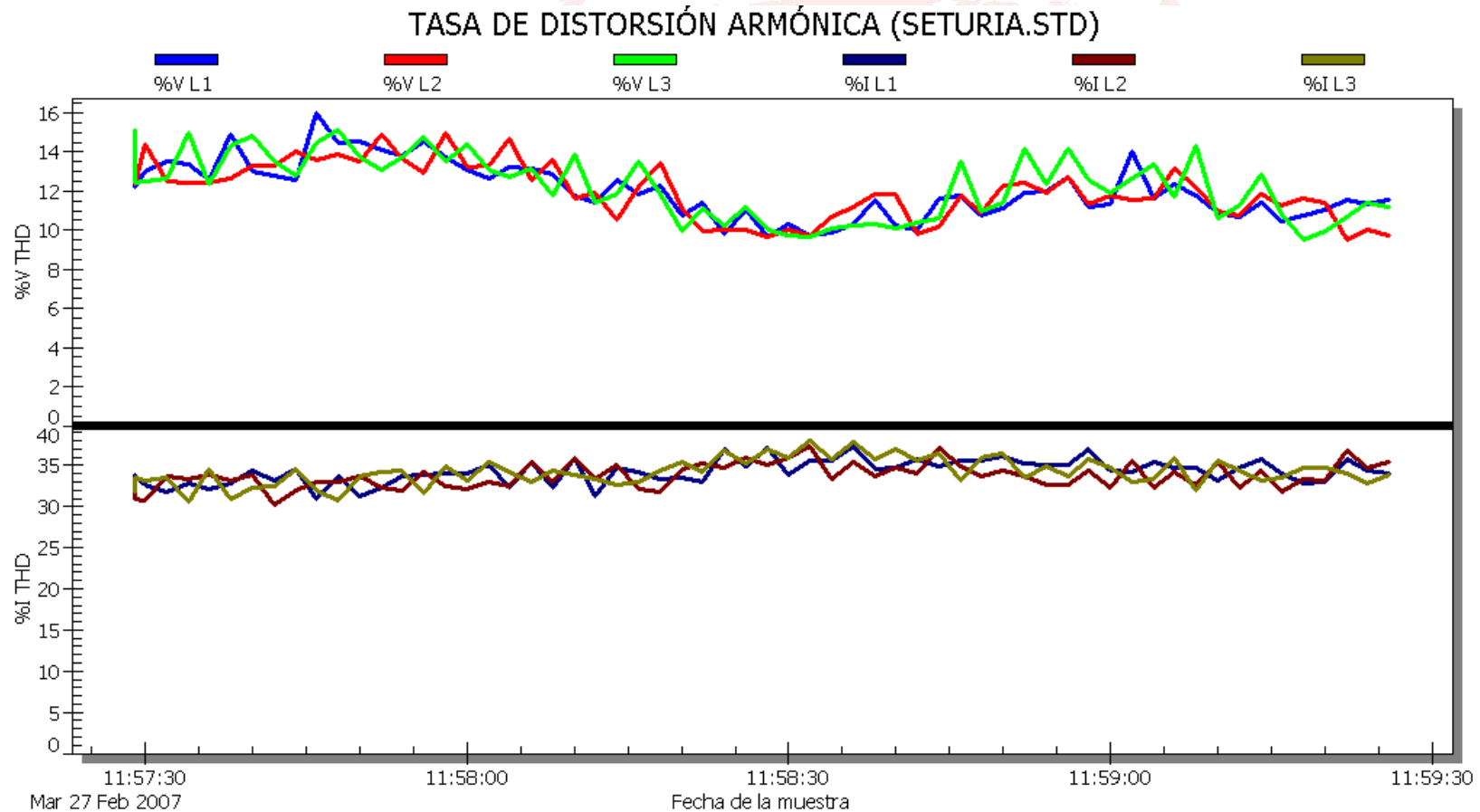
Points of measure: 1,2,3,4,5,6

Parameters	Irms	1	3	5	7	11	13	Σ THD
Voltage								
Current								
Neutral								

If there is a capacitor bank...

WITH CAPACITOR BANK CONNECTED		WITH CAPACITOR BANK DISCONNECTED	
THD(I)	%	THD(I)	%
THD(U)	%	THD(U)	%
Q(Power of CB)		kvar	
P(Installation)		kW	

Example (I): Q Compensation



Act : 27/02/2007 11:57:29
Act : 13.3 (%V THD)

Variable Seleccionada: %V L1
Desde : 27/02/2007 11:57:29
Máx : 16.0 (%V THD)

Hasta : 27/02/2007 11:59:26
Min : 9.7 (%V THD)

Example (II): Resonance effect

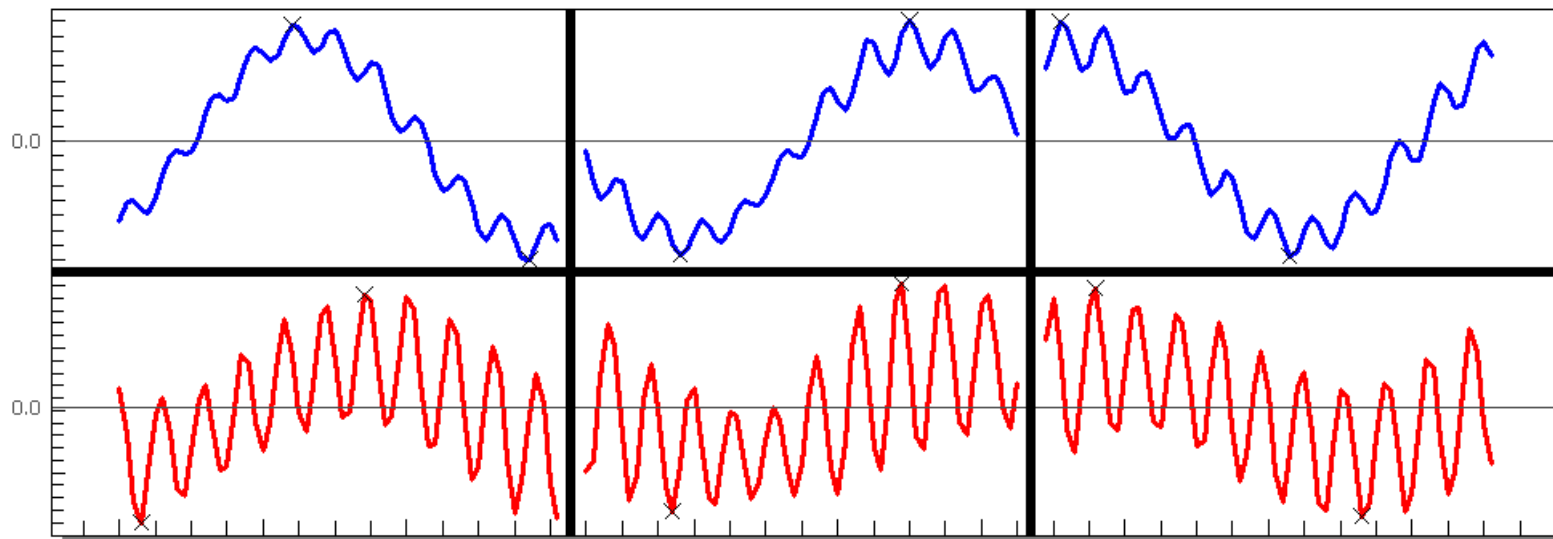
FORMA DE ONDA (----.STD)

13/02/2007 16:40:33

Vn F1: 228 (V)
THD: 16.7 %
Máx: 361 (V)
Mín: -373 (V)

Vn F2: 228 (V)
THD: 19.6 %
Máx: 393 (V)
Mín: -374 (V)

Vn F3: 229 (V)
THD: 23.0 %
Máx: 398 (V)
Mín: -387 (V)



In F1: 216.506 (A)
THD: 80.2 %
Máx: 682.800 (A)
Mín: -710.800 (A)

In F2: 253.152 (A)
THD: 83.0 %
Máx: 891.600 (A)
Mín: -750.000 (A)

In F3: 248.702 (A)
THD: 85.8 %
Máx: 949.200 (A)
Mín: -873.200 (A)

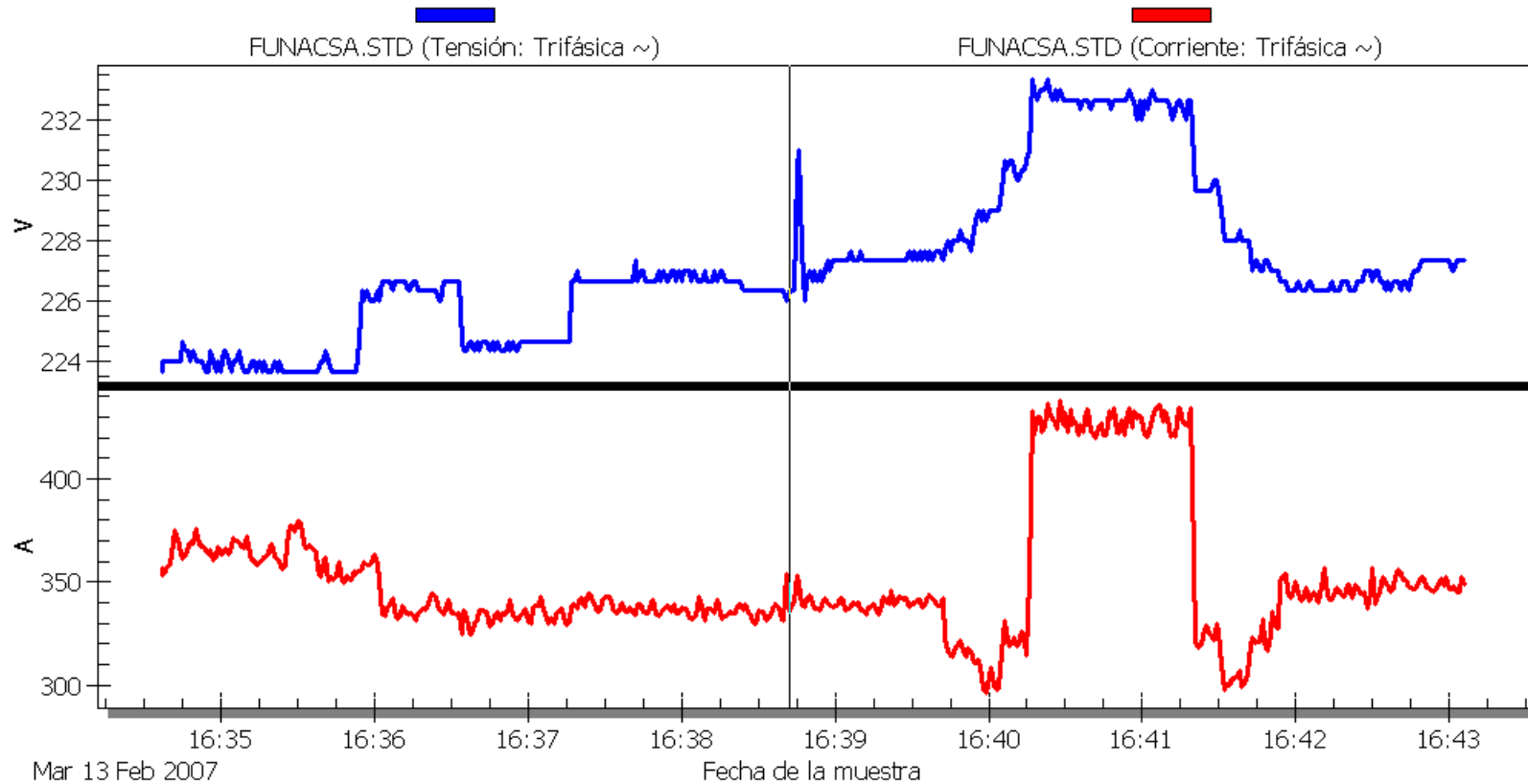
Act : -250 (V)

Máx : 361 (V)

Mín : -373 (V)

Example (II): Resonance Effect

Niveles de Tensión y Corriente



Variable Seleccionada: FUNACSA.STD (Tensión: Trifásica ~)

Act : 13/02/2007 16:38:42

Desde : 13/02/2007 16:34:37

Hasta : 13/02/2007 16:43:06

Act : 226 (V)

Máx : 233 (V)

Mín : 224 (V)

Example (III): Transformer

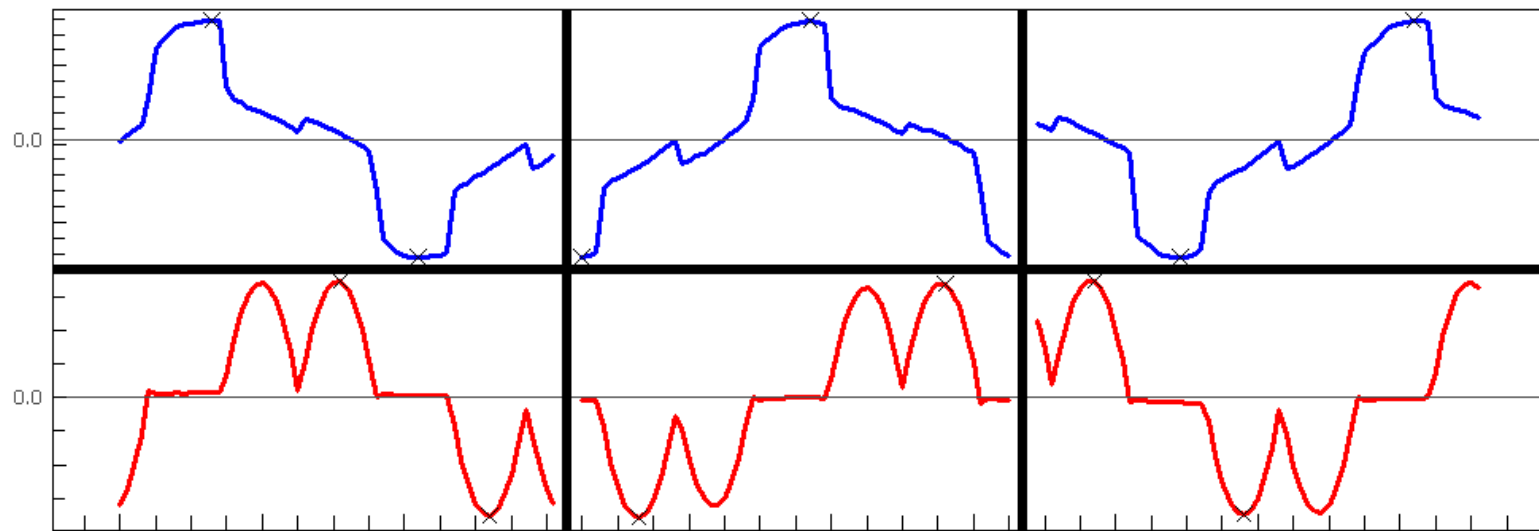
FORMA DE ONDA (MIX5_M2.A5I)

10/01/2007 14:00:00

Vn F1: 377 (V)
THD: 45.7 %
Máx: 766 (V)
Mín: -744 (V)

Vn F2: 368 (V)
THD: 46.7 %
Máx: 757 (V)
Mín: -739 (V)

Vn F3: 357 (V)
THD: 48.0 %
Máx: 747 (V)
Mín: -729 (V)



In F1: 907 (A)
THD: 45.2 %
Máx: 1689 (A)
Mín: -1712 (A)

In F2: 915 (A)
THD: 44.4 %
Máx: 1702 (A)
Mín: -1793 (A)

In F3: 928 (A)
THD: 44.0 %
Máx: 1712 (A)
Mín: -1726 (A)

Act : -3 (V)

Máx : 766 (V)

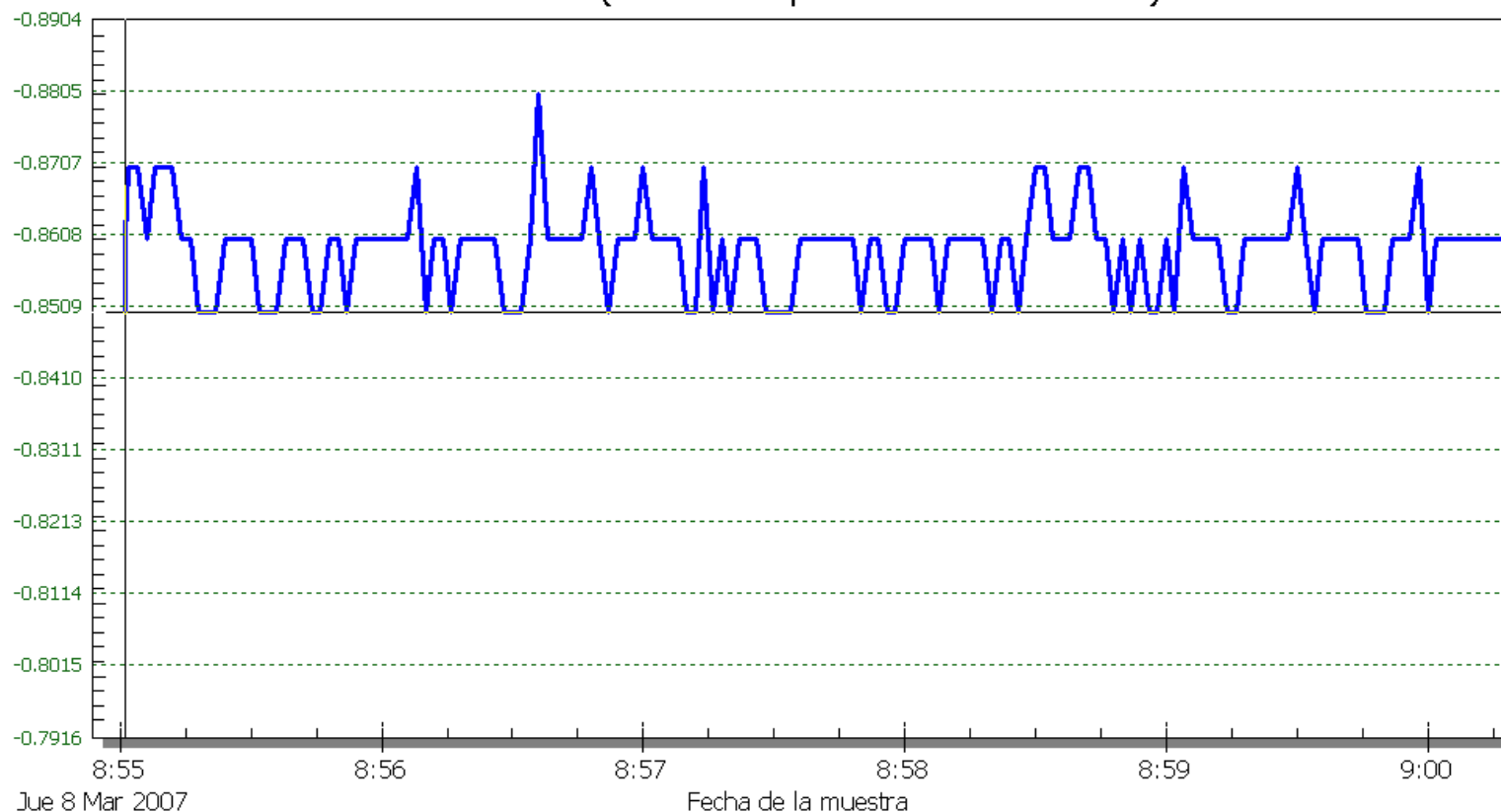
Mín : -744 (V)

Example (IV): Office

MULTIGRÁFICA



SALA3.STD (Factor de potencia: Trifásica +)



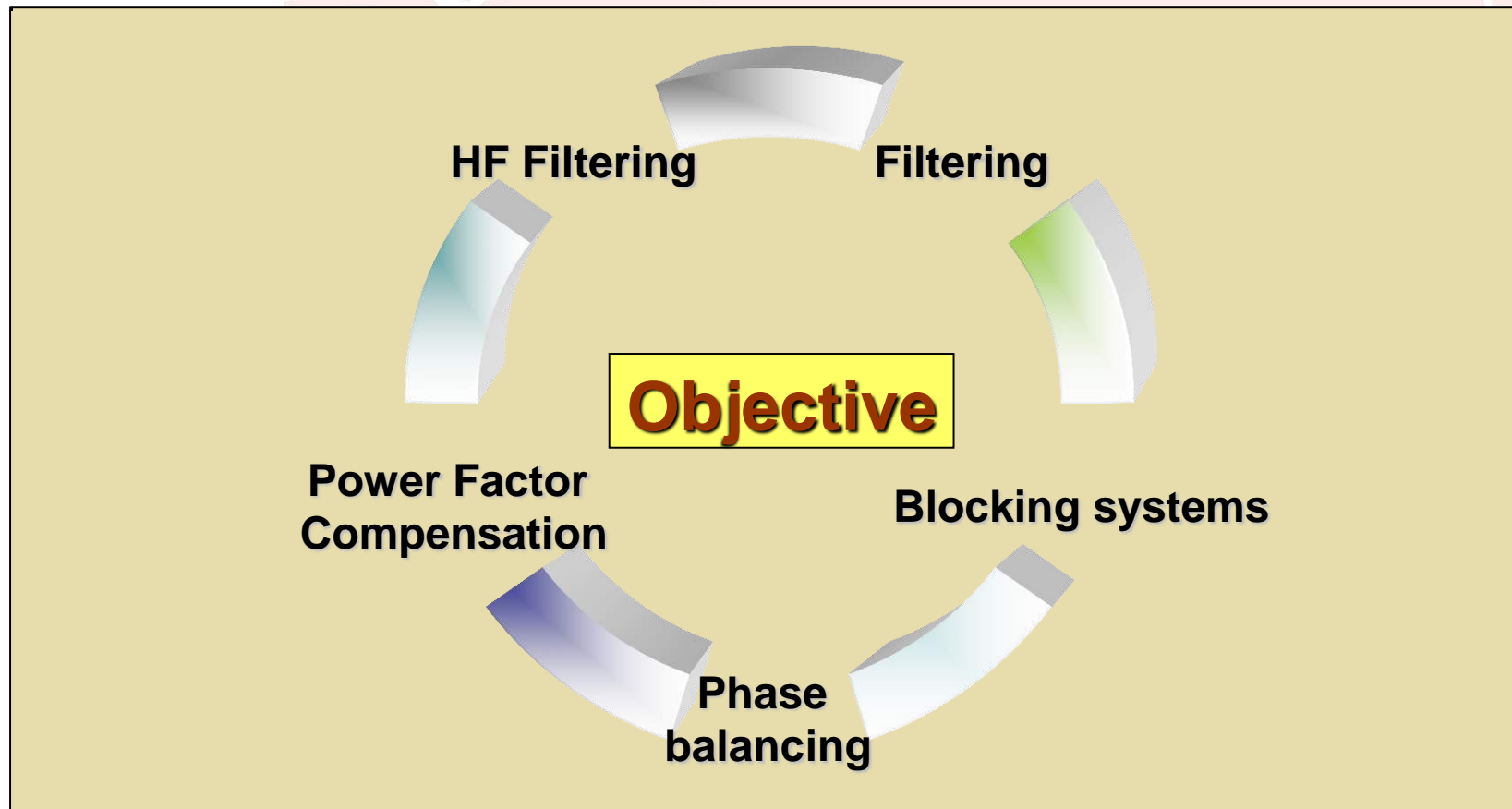
Act : 08/03/2007 08:55:01
Act : -0.85

Desde : 08/03/2007 08:55:01
Máx : -0.88

Hasta : 08/03/2007 09:01:14
Mín : -0.61

Solutions

Accordingly, all the possible objectives



Defining Objective: PFC

Power factor compensation in the presence of harmonics:

- **Detuned banks** with electro-mechanic contactors
(FR Series)
- **Static detuned banks** with static contactors (thyristors)
(FRE Series) when:
 - ✓ Charges are very variable.
 - ✓ Need of avoiding transients

✓ **Protecting capacitors and networks of overloads and amplifications when compensating PF**

Defining Objective: Harmonic Filtering

To reduce the THDI :

- **FA absorption filters** . Passive filters with different tunings according each case.
- **LCL absorption filters** Passive filters for 6 pulses converters THDI reduction (5th and 7 th harmonic)
- **APF Active filters.** For the electronic compensation of a wide range of harmonics.
- **Sinus Filter.** For avoid overvoltage and malfunction in electric motors after converter.

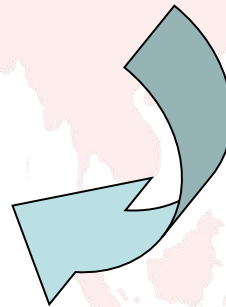
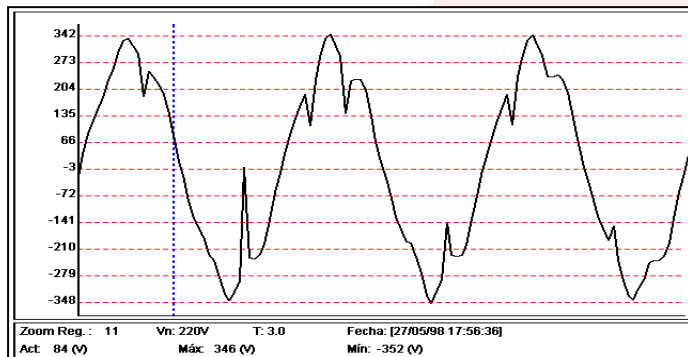
- ✓ **Arranging of I and V waveform**
- ✓ **Decreasing of the active losses (kW), so money saving**
- ✓ **Discharge of cables**
- ✓ **Avoiding malfunctions of equipments**

Defining Objective: HF Filtering

To avoid the flow of HF currents :

- **EMR Single phase EMI Filters.**
- **EMR Three phase EMI filters**
 - 3 wires EMI filters for VSD
 - 4 wires EMI filters for UPS

- ✓ **Control of HF current and voltage generated by commutation effects**
- ✓ **To avoid dv/dt in voltage wave**
- ✓ **To avoid wrong operations of PLC, control equipments..**



Defining Objective: Phase Symmetry

To balance the current of the phases:

➤ ***APF active filter***

***Balances the current of the phases
upstream of the connecting point***

Harmonic Filtering Strategies

Location

Effects

LV General Panel



✓ To reduce the THDI at the utility network (above point of common coupling).

Secondary Panel



✓ Reduces RMS current at main distribution line without decreasing active power.
✓ Decreasing of Losses

Individual Filtering



✓ Reduces RMS current just in the place harmonics are generated.
✓ Reduces Losses in the whole distribution system.

DETUNED FILTER

How it works?:

- Compensate reactive power and avoid resonance effects.

How to select it?

- When THD(V) initial is aprox. $> 2,5\%$
- When standard Capacitor Bank produce amplification of THD(V)
- Always when at the installation there are drives and converters.

Models: (FR, FRE)

- $p = 7\%$: To installation where there are so much disturbance loads (fundamental drives) and poor level of 3rd harmonic of current.
- $p=14\%$, To install where there are so much loads that generate 3rd harmonic.



p%	wr	Armónico rechazado
7%	189 Hz	$h > 5^{\circ}$, $f > 250\text{Hz}$
14%	134 Hz	$h > 3^{\circ}$, $f > 150\text{Hz}$

Absorption Filter & Hibrid Filter

How it works?:

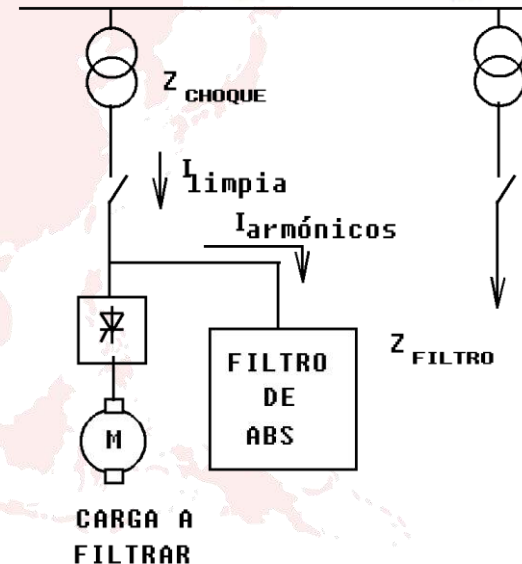
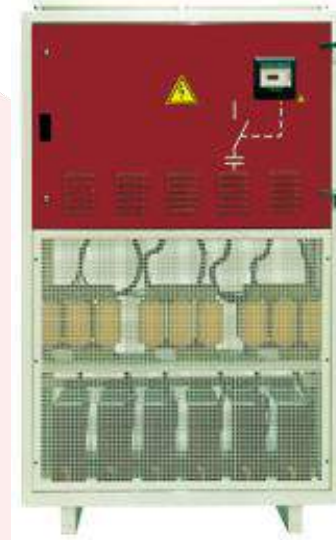
- Absorbe current of 5th and 7th harmonic (other harmonic could be available)
- Regulate reactive power in the installation.

How to select?

- When ther are 5th and 7th harmonic and you want compansate and also filtering

Models: (FAR-H, FAR-Q, FARE-Q)

- FAR-H: Absolutly tuned at harmonic frequency. Important: its necessary a more accurate study, because a wrong regulation, filter could not work properly.
- FAR-Q/FARE-Q: Special tuned to provide more compensation, but also absorbe 5th and 7th harmonic.



Converter's Filter: LCL

How it works?:

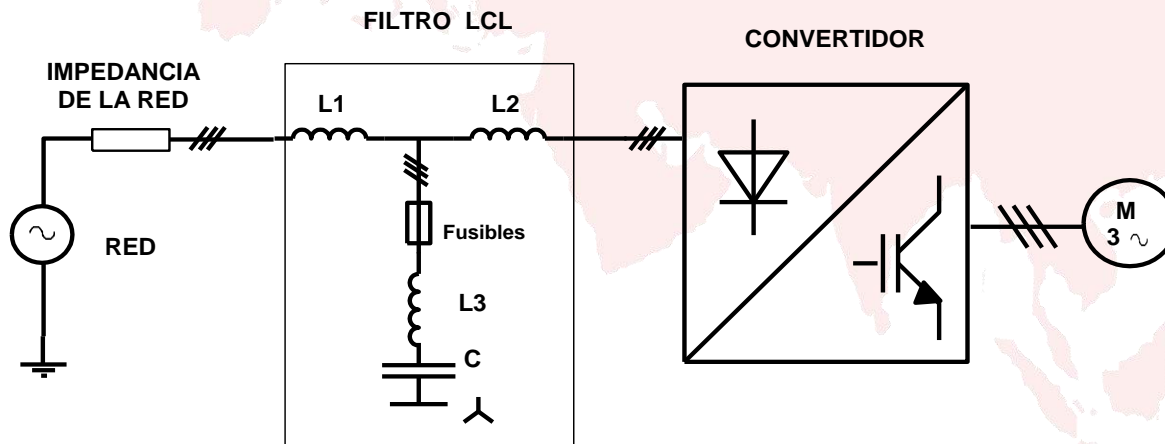
- Special passive filters for individual filtering of 6P converters (drives, rectifier, UPS, etc.).

How to select?

- When there are 5th and 7th harmonic and you want filtering directly at load.

Models: LCL & LCL-TH

- To agree with standard EN-61000-3-4 & IEEE-519



Why to install LCL filters?

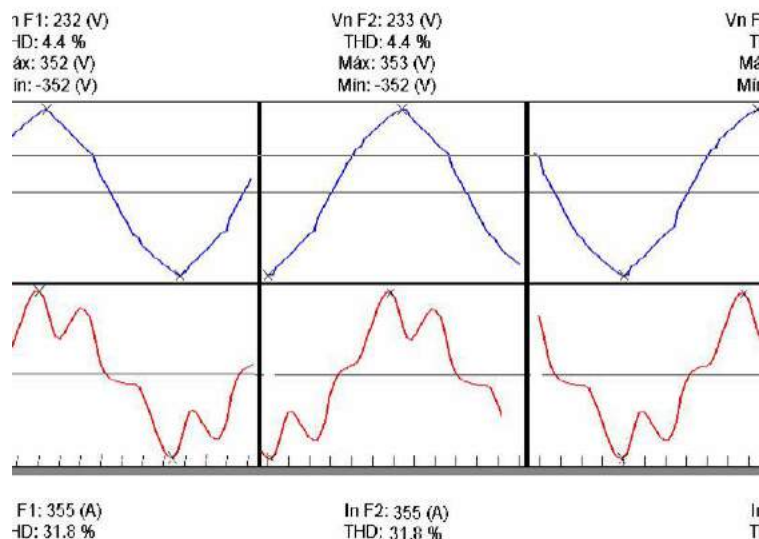
- ❑ To reduce the THD in current to values below 10% according with IEC 61000-3-4 and IEEE-519.
- ❑ There is a load fitted with a converter of 6 pulses.
- ❑ Energy saving by the reduction of the RMS current ,and so that, reduction of KVA.
- ❑ No need to forecast any future expansion of the installation.
- ❑ Increase the equipment life consequence of the decrease the losses by hot produced by the harmonics.
- ❑ Strong equipment with a very low maintenance.
- ❑ Lower price comparing with other systems of filtering

LCL real case

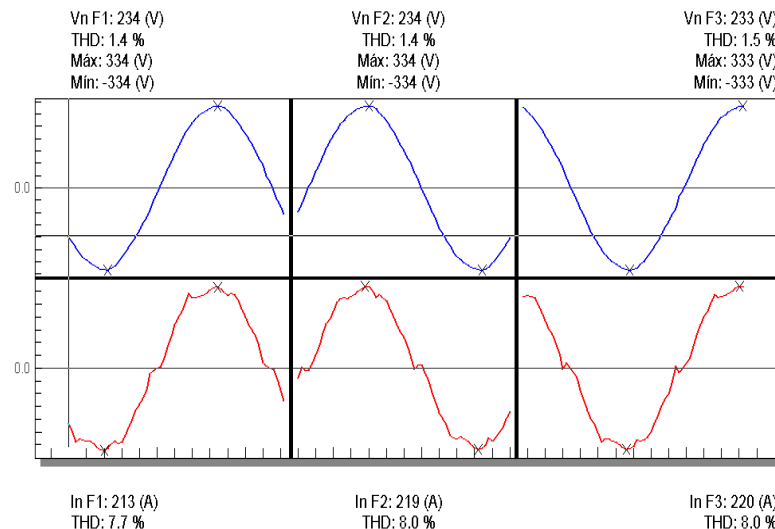
WITHOUT FILTER

WITH FILTER, 70% OF LOAD

FORMA DE ONDA (ccm9tr22.a5i)
21/11/2001 15:48:40



FORMA DE ONDA (TPDCLC.A5I)
19/08/1992 11:22:04



Corriente de línea sin filtro, THD(I)=32%; THD(V)=4,4%

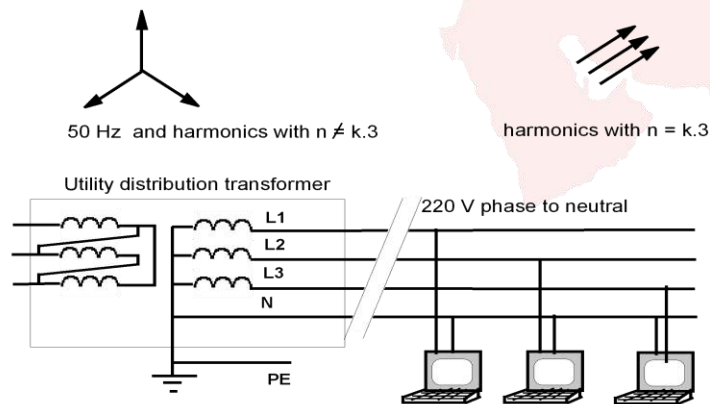
Corriente de línea con filtro, THD(I)=8%; THD(V)=1,4%

3rd Harmonic blocking system: TSA

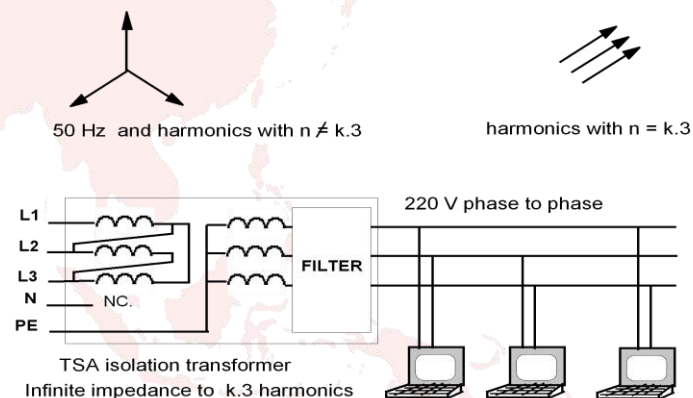
- ✓ The TSA is a blocking system made by:
 - ❑ Insulating D-y transformer
 - ❑ 5th harmonic filter
- ✓ The objective is to avoid the flow of the 3th harmonic in the secondary, so in the network
- ✓ To filter the 5th harmonic



Without Filter

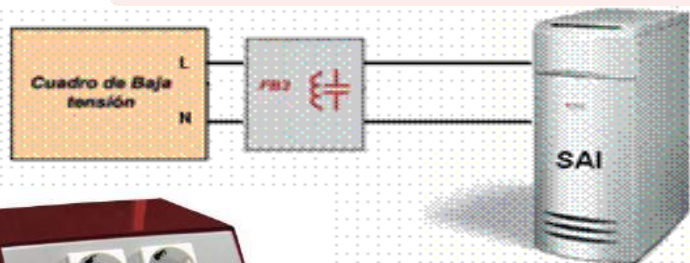
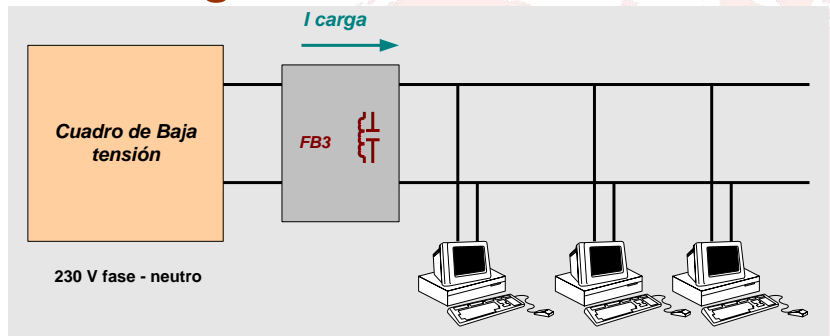


With Filter

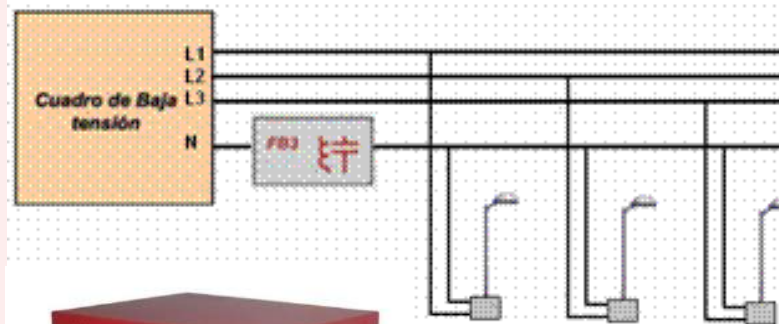
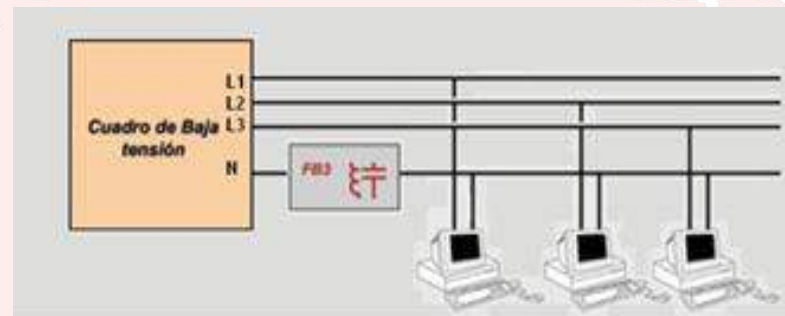


3rd Harmonic blocking system: FB3/T

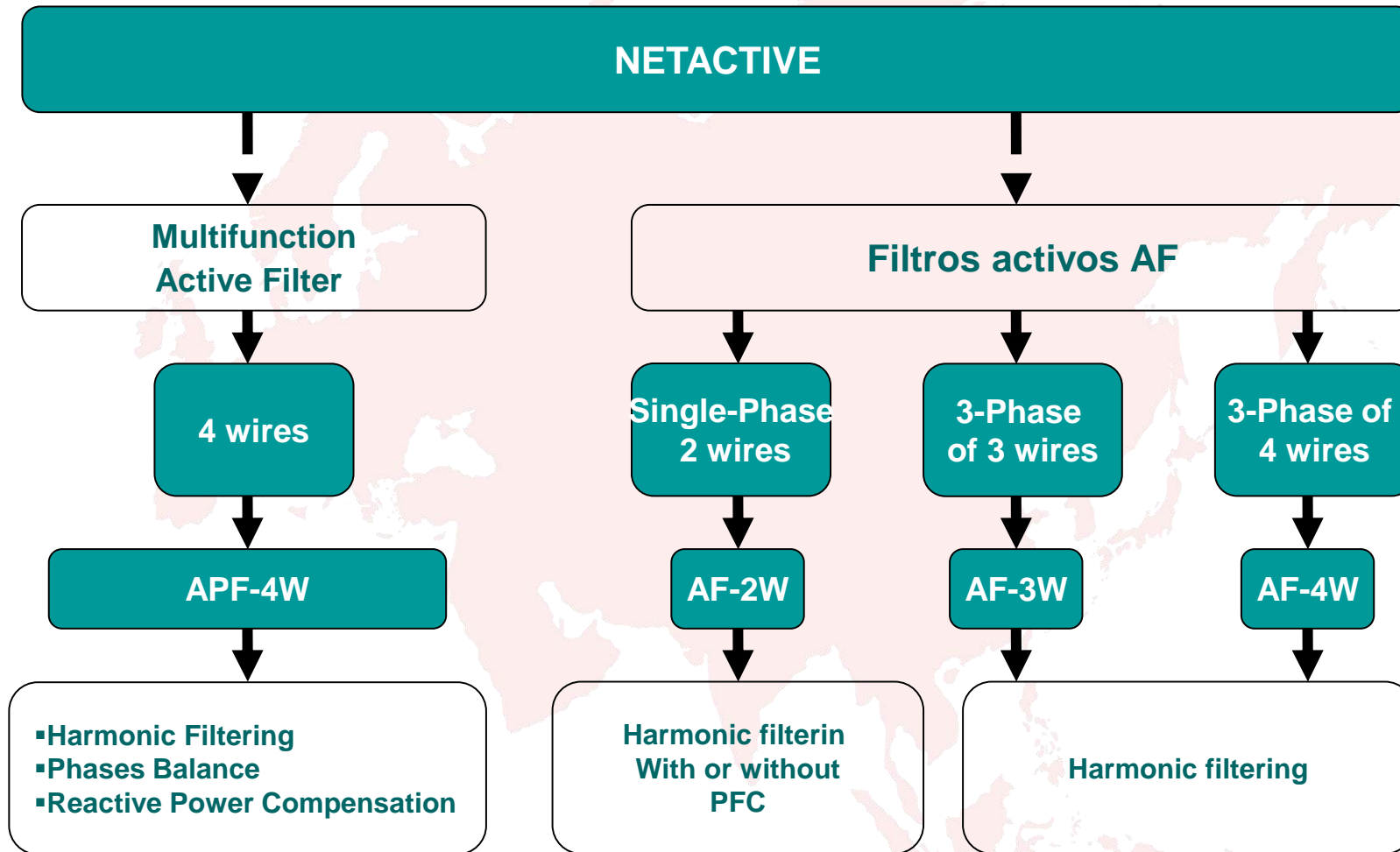
Single-Phase Installation



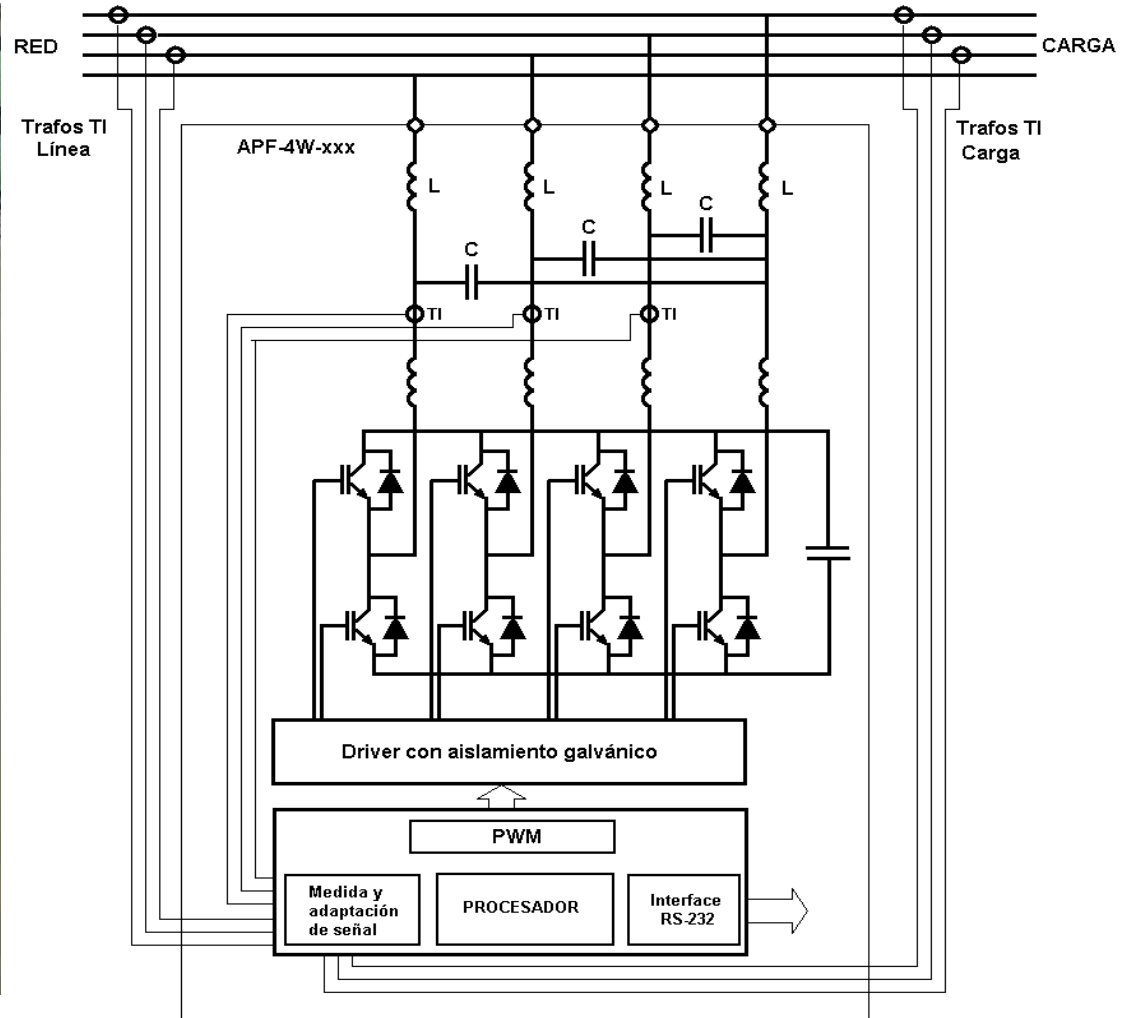
3-Phase Installation



Active Filters

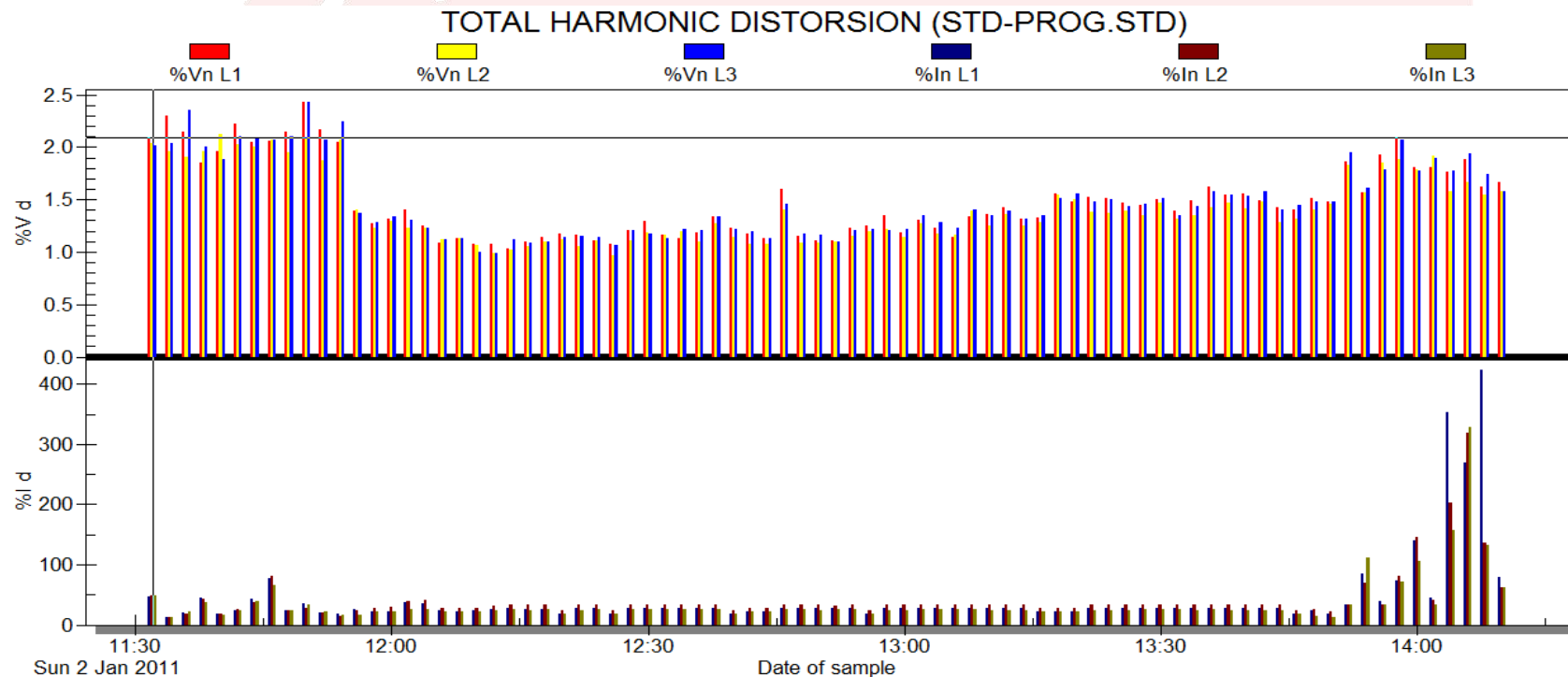


Active Filters



GE Wind Power

•THD I and V



Act : 02-01-2011 11:32:00
Act : 2.10 (%V d)

Selected Variable: %Vn L1
From : 02-01-2011 11:32:00
Maximum : 2.43 (%V d)

To : 02-01-2011 14:10:00
Minimum : 1.04 (%V d)

Thank You

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