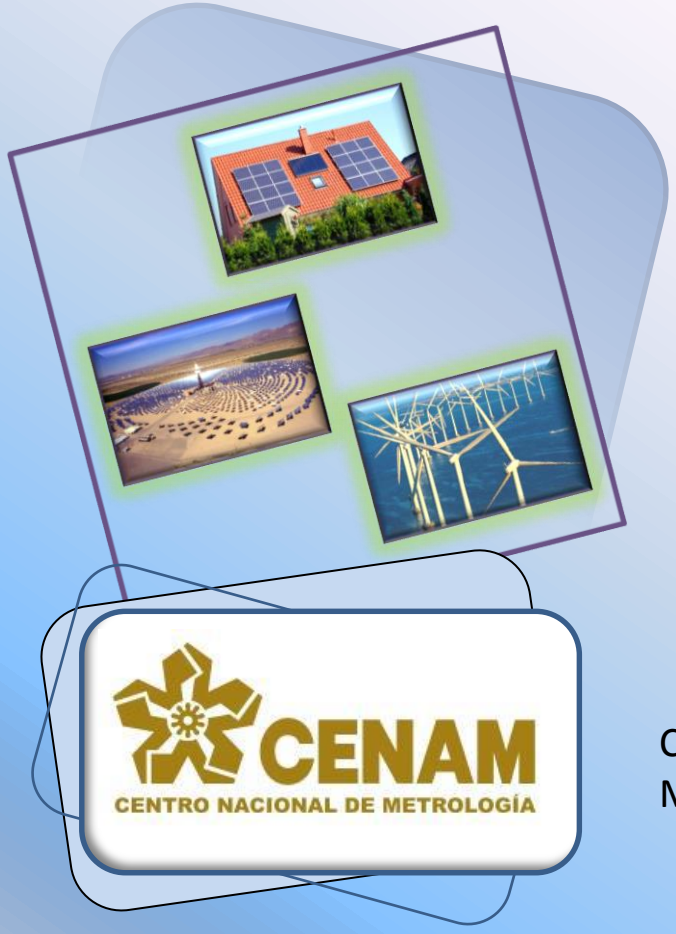


What reliable measurements can do to ensure the interoperability of electric grids for renewable energies?

RENÉ CARRANZA

CENAM is the National Metrology Institute of México

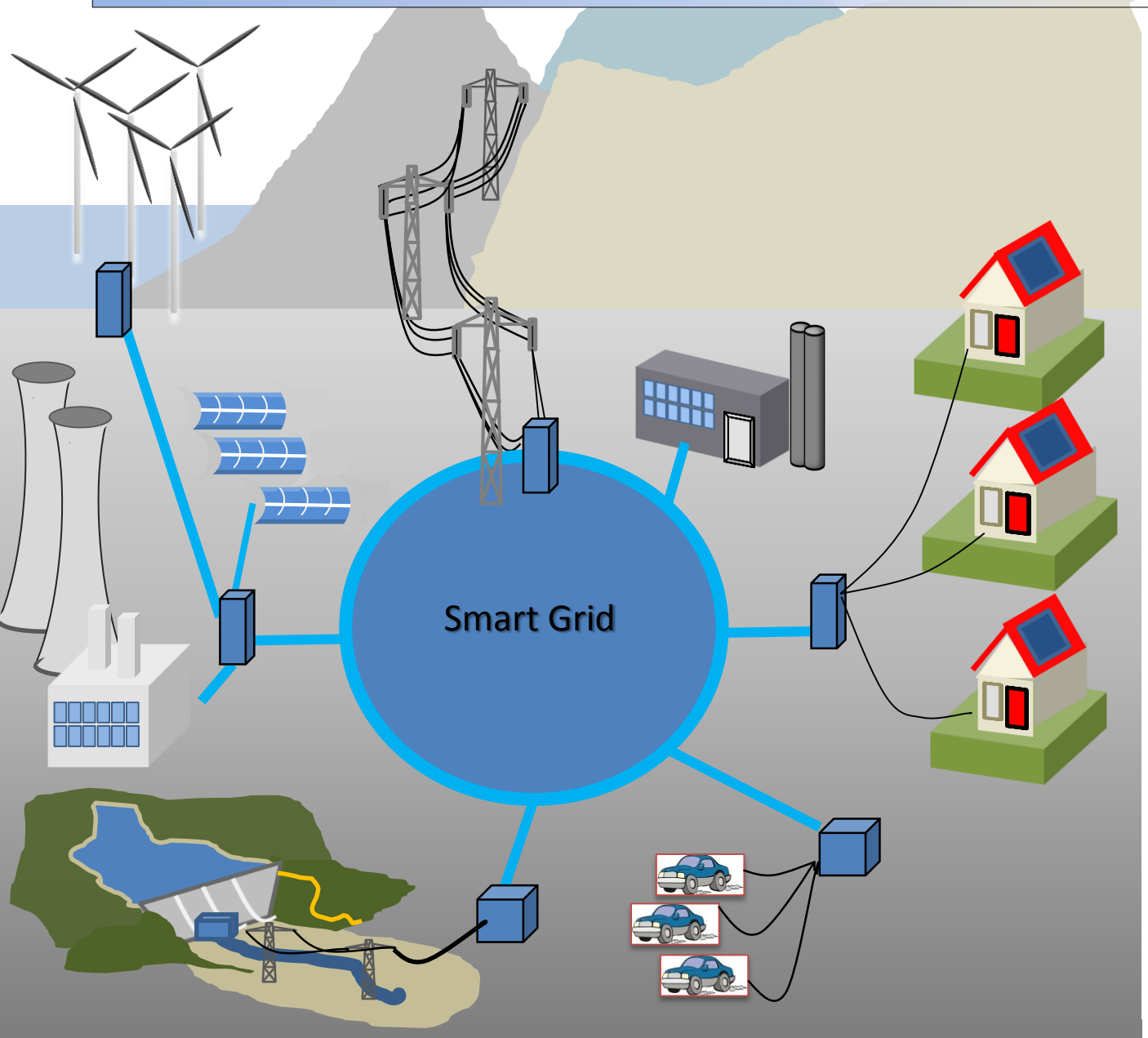
"Interoperability: the ability of two or more systems or components to exchange information and to use the information that has been exchanged"

IEC Smart Grid Standardization Roadmap/1/2010

Interoperability in Smart Grids:

- Syntactic interoperability: the ability to communicate and exchange data (standardized data formats and protocols)
- Semantic interoperability: the ability to automatically interpret the exchanged data

Renewable energies in Smart Grid planning



Needs:

- Bidirectional power flow measurement
- Remote and Local Generation
- Wide Area Networks: monitoring, protection and control
- Fluctuating energy sources (wind, photovoltaic, geothermal, wave)
- Smart metering: energy use savings

Musts:

- Measurement of large amounts of power at the right time & place
- New measurement tools and methods

Renewable energies in Smart Grid planning

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Renewable Energies + **Demand** = **Intelligent Electric Networks**

Intermittent generation

Non lineal loads

Vulnerability to the Quality of Power in the grid

Time varying loads

- Technology standards
- Real time measurement tools and methods

Renewable energies in Smart Grid planning

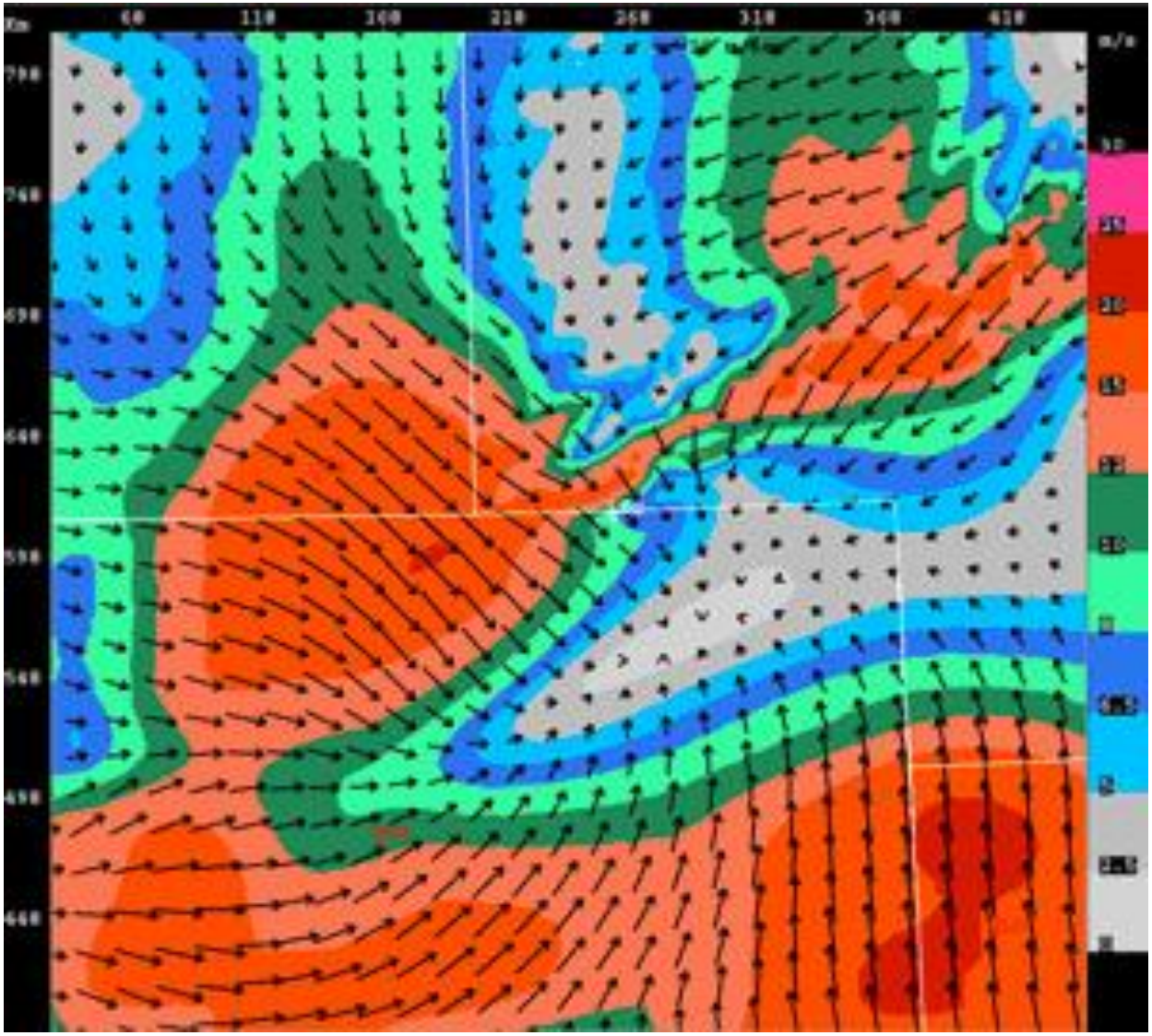

Image: NACAR/IEEE Spectrum, March 2016

Taming Wind Power With Better Forecasts Sophisticated weather simulations are making wind power more grid friendly, Sue Ellen Haupt & William P. Mahoney

Intermittent by nature

Variational Doppler Radar Analysis System (VDRAS). Colorado and neighbor states, USA.

Wind speed:

gray: reduced wind speed

Red: increased wind speed

IEC 61400-21:2008 Wind turbine QP characteristics

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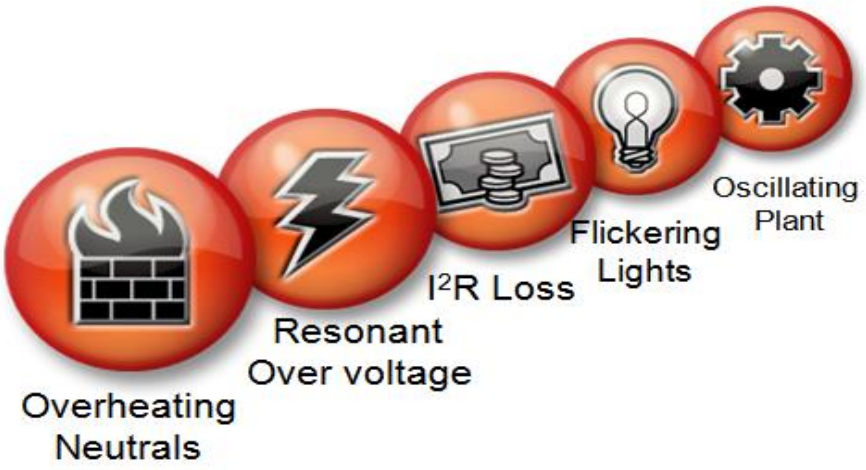
Operating conditions of the turbine	Characteristics of Quality of Power of a Wind Turbine to be determined/tested	
Continuous operation	Flicker coefficient determined at different phase angles of impedance of the network	
Switching conditions	Maximum number of switching operations @ 10 min and 2 h.	Flicker at different phase angles of the impedance of the network
Current harmonics, interharmonics	Percentage of the fundamental current component . 50ª harmonic	BIN's of active power: 0, 10 … 100 %
Response to voltage drops	Voltage amplitude	Duration and waveform
Active power	Set point control	Supporting the frequency automatic control
Reactive power	Set point control	Supporting the voltage automatic control
Grid protection	Disconnection levels	Disconnection times
Reconnection time	Due to faults on the network	

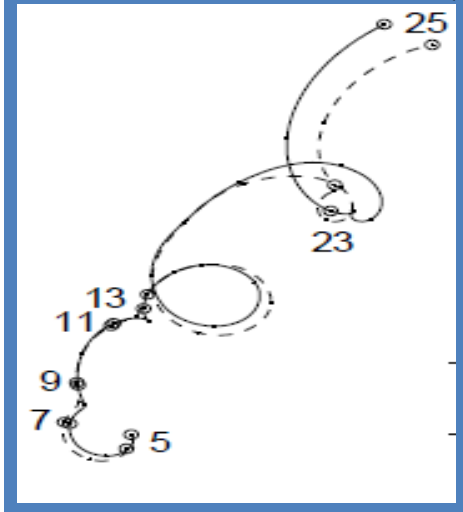
Renewable energies: power quality



Study (Leonardo Institute):

"PQ costs in Europe are responsible for serious reduction in industrial performance with an economic impact exceeding € 150 bn/year"

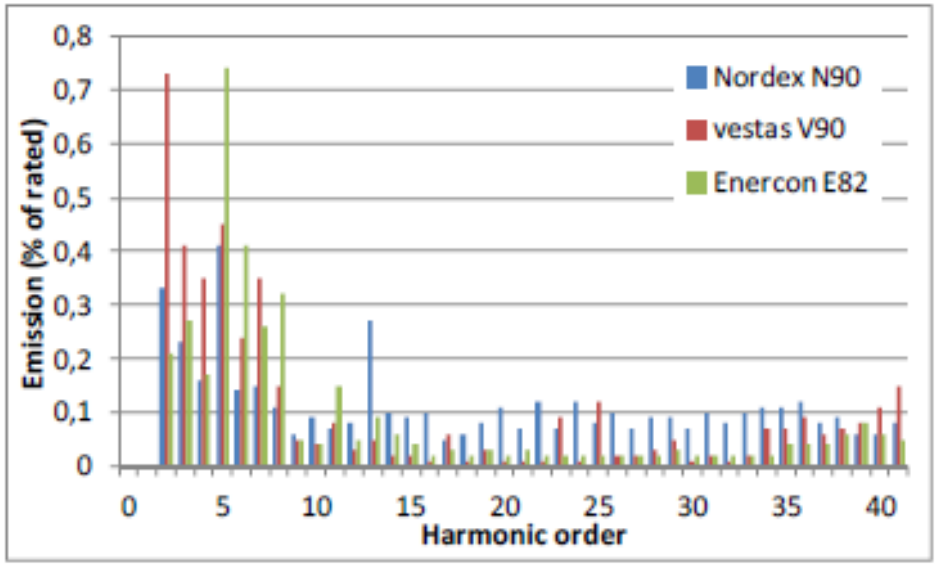
Wide Area Quality of Power



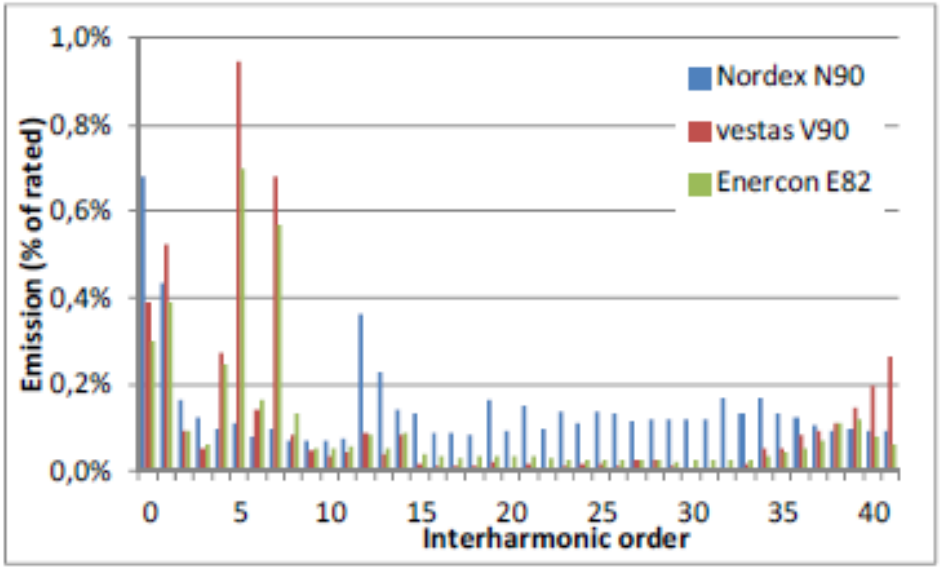
Network impedance

On-site tests on renewable sources

Renewable energies: wind turbine power quality



Emission spectrum (harmonic subgroups) from three modern MW-class wind turbines (2 to 2.5 MW)



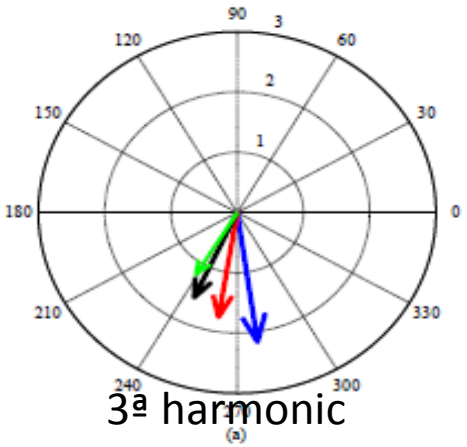
Emission spectrum (interharmonic subgroups) from three modern MW-class wind turbines (2 to 2.5 MW)

Bollen, M,. and Yang K., "Harmonics – another aspect of the interaction between wind power installations and the grid", 22nd International Conference on Electricity Distribution, CIRED, June 2013

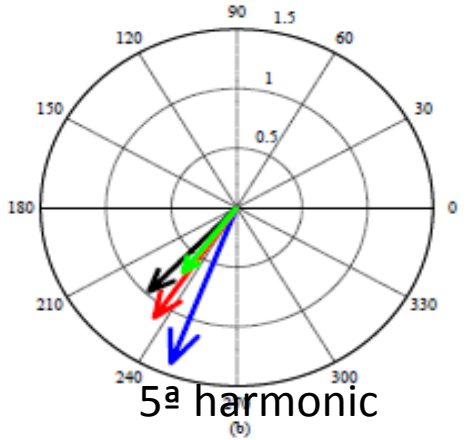
Renewable energies: photovoltaic power quality

The effects of harmonics on the phase angle of a PV inverter

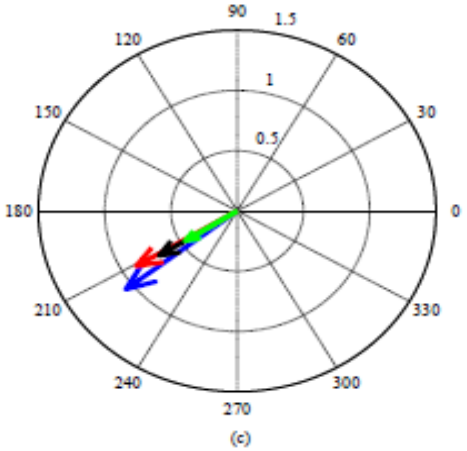
Power:
100 % (**blue**)
75 % (**red**)
50 % (**black**)
25 % (**green**)



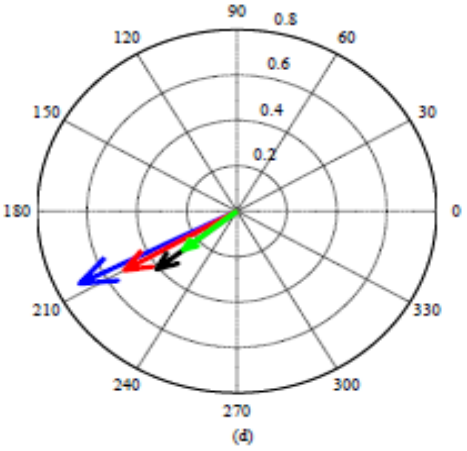
3ª harmonic



5ª harmonic



7ª harmonic



9ª harmonic

Perera D. et al, "Power quality emission assessment of photovoltaic inverters based on IEC technical report 61000-3-15:2011", IEEE AUPEC 2013

Reliable measurements: syntactic and semantic interoperability

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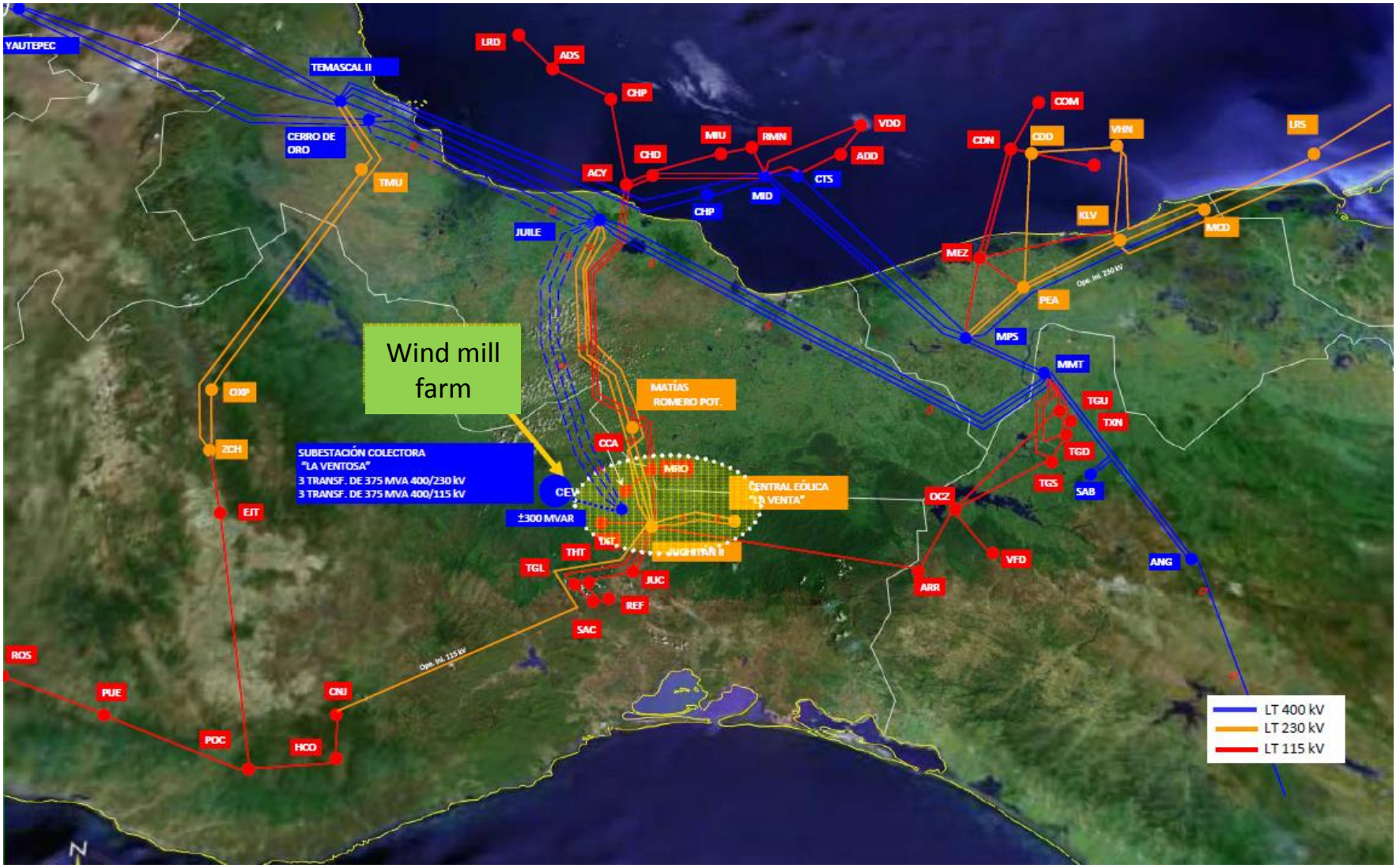
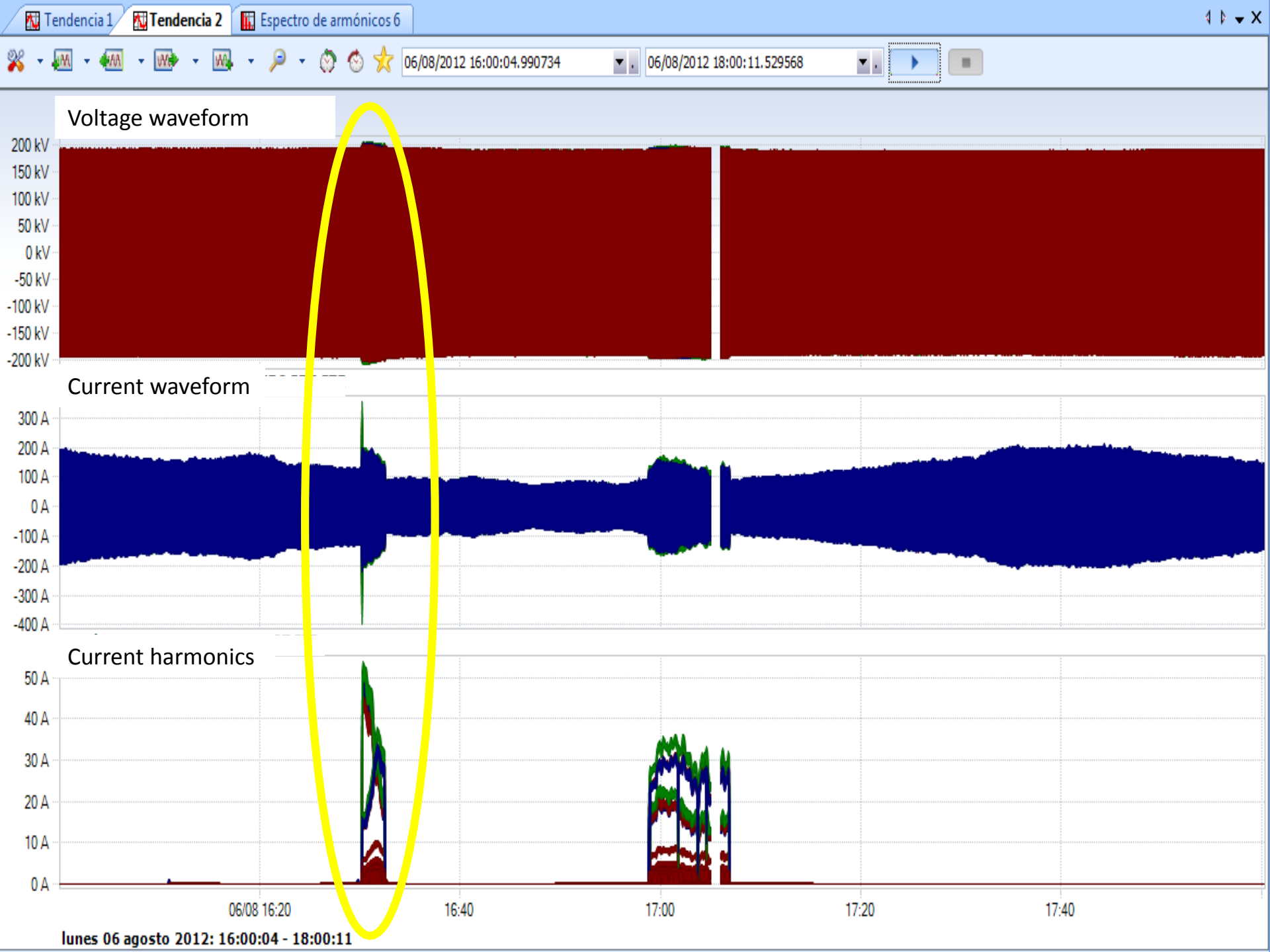
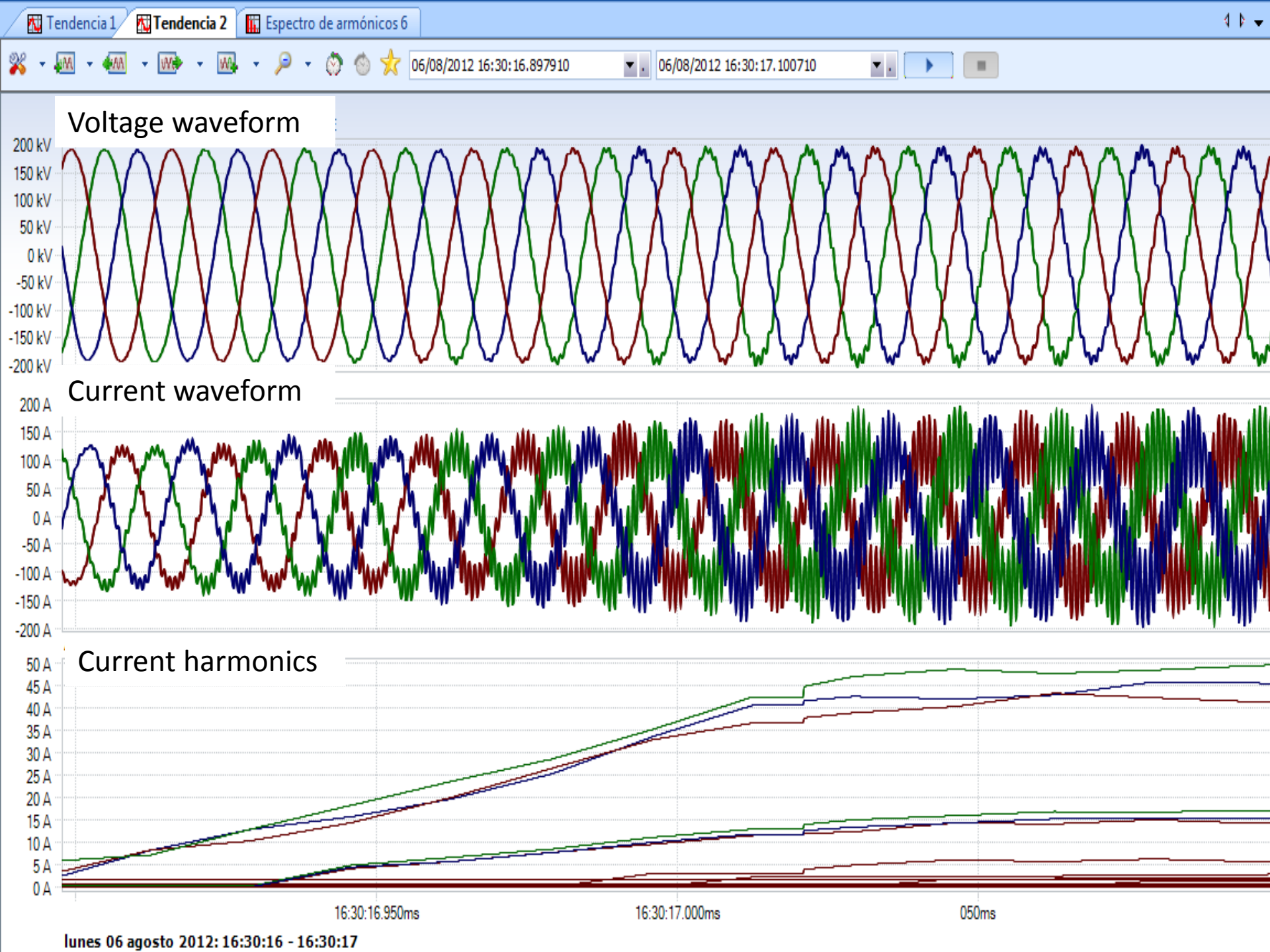
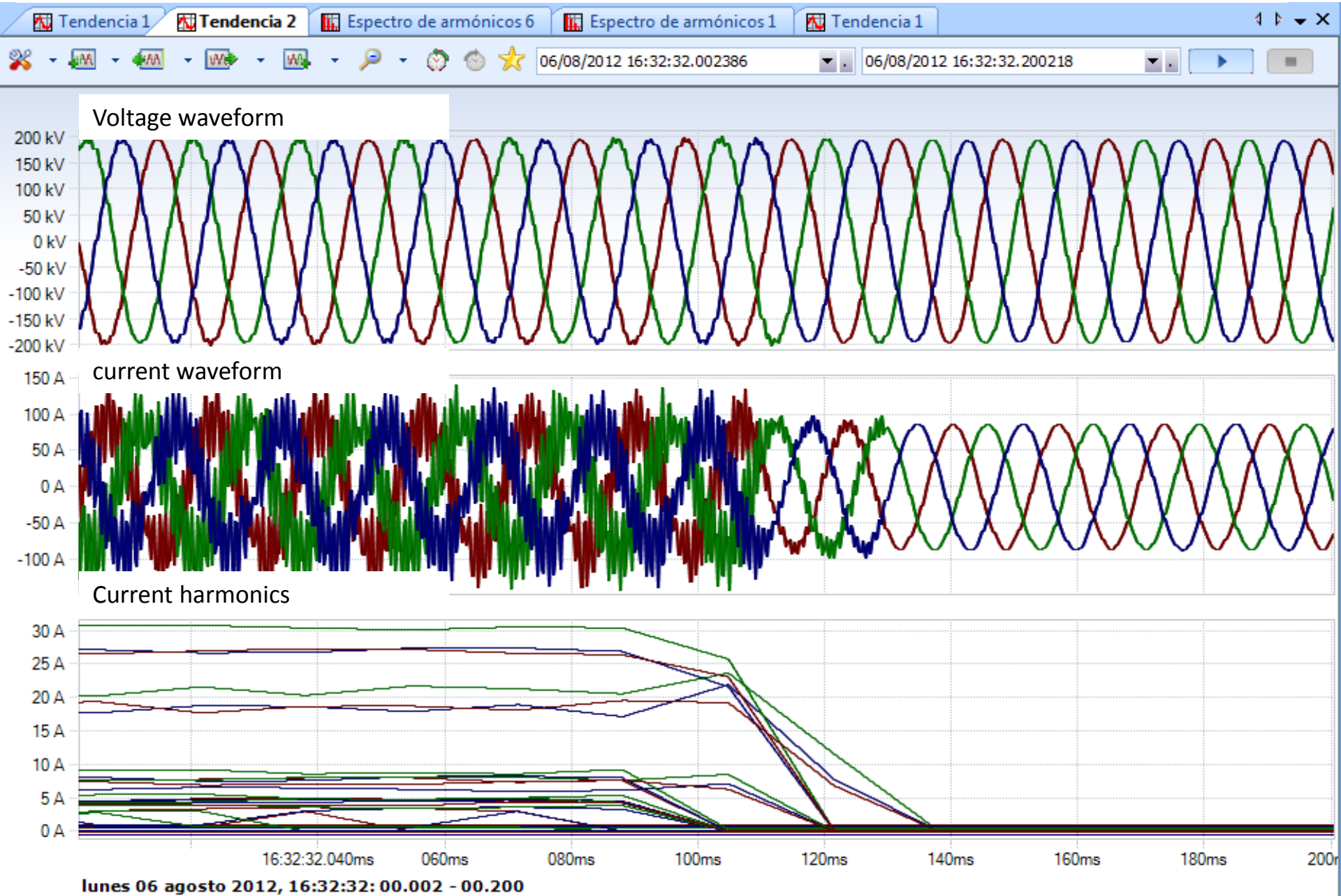


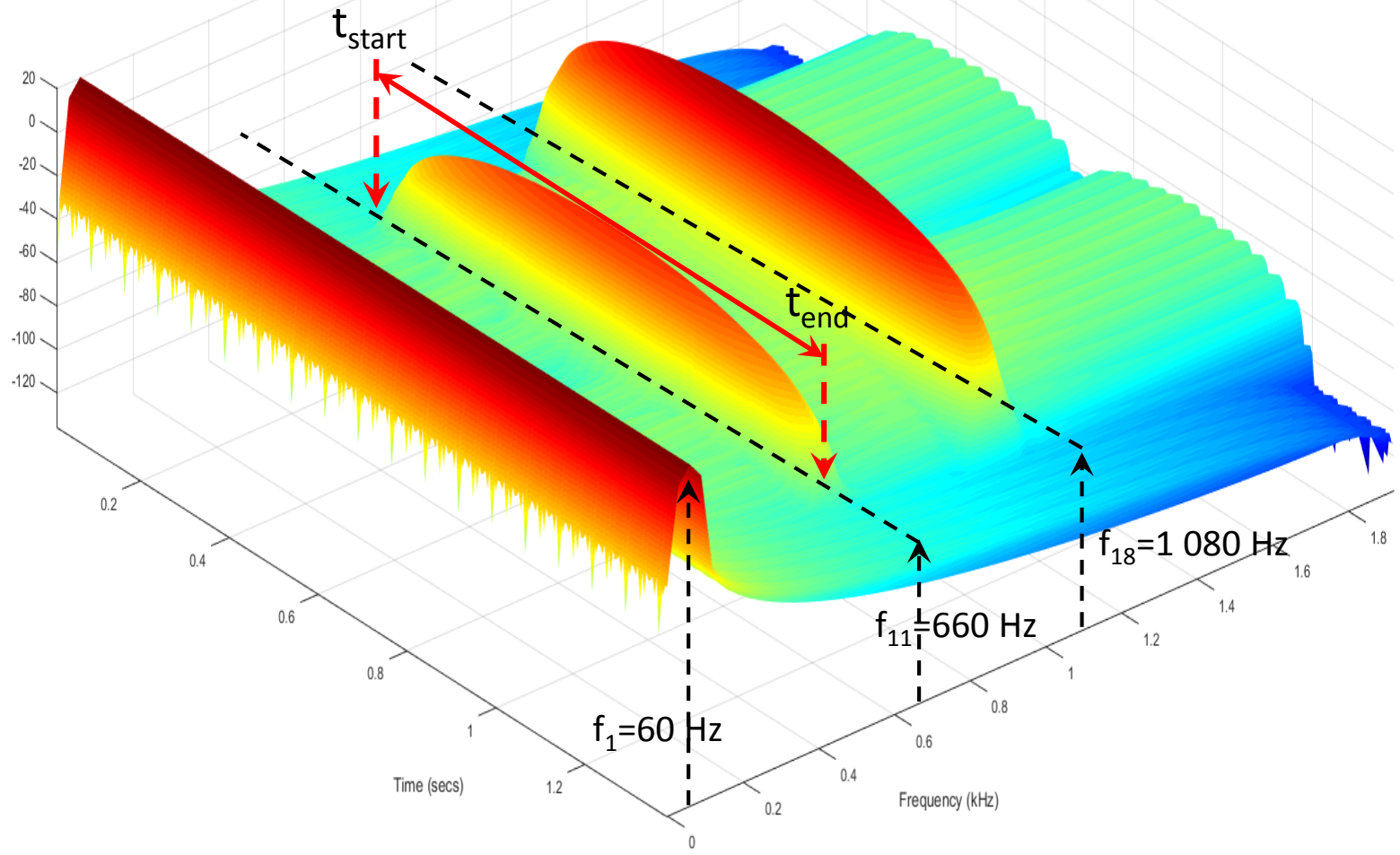

Tendencia 1
Tendencia 2
Espectro de armónicos 6
06/08/2012 16:00:04.990734
06/08/2012 18:00:11.529568
Voltage waveform
200 kV
150 kV
100 kV
50 kV
0 kV
-50 kV
-100 kV
-150 kV
-200 kV
Current waveform
300 A
200 A
100 A
0 A
-100 A
-200 A
-300 A
-400 A
Current harmonics
50 A
40 A
30 A
20 A
10 A
0 A
06/08 16:20
16:40
17:00
17:20
17:40
lunes 06 agosto 2012: 16:00:04 - 18:00:11


Tendencia 1
Tendencia 2
Espectro de armónicos 6
06/08/2012 16:30:16.897910
06/08/2012 16:30:17.100710
Voltage waveform
200 kV
150 kV
100 kV
50 kV
0 kV
-50 kV
-100 kV
-150 kV
-200 kV
Current waveform
200 A
150 A
100 A
50 A
0 A
-50 A
-100 A
-150 A
-200 A
Current harmonics
50 A
45 A
40 A
35 A
30 A
25 A
20 A
15 A
10 A
5 A
0 A
16:30:16.950ms
16:30:17.000ms
050ms
lunes 06 agosto 2012: 16:30:16 - 16:30:17

Harmonic distortion ends at 16:32:32 due to the opening of the high voltage circuit



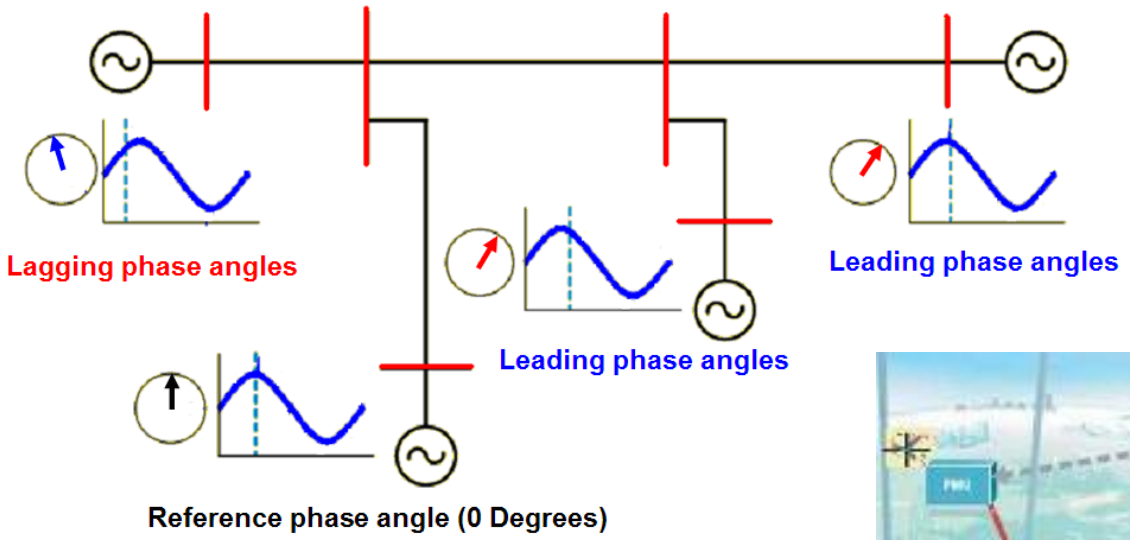
Time and Frequency Measurement Method/CENAM



Analysis of the current during the fault: harmonics 11th and 18th

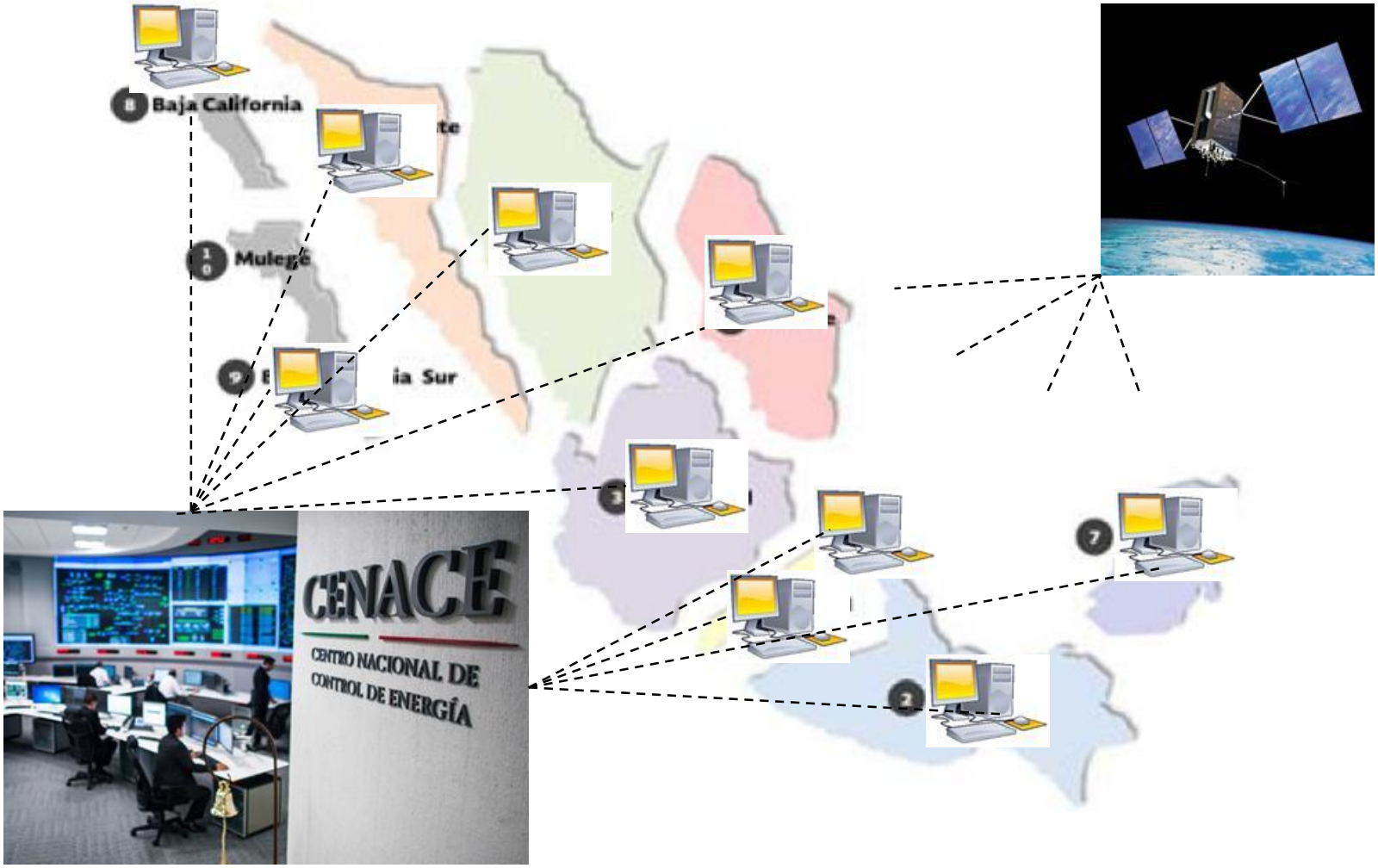
Reliable measurements: syntactic and semantic interoperability

IEEE Std. C37.118.1- 2011/ 2014. Synchrophasor Measurements for Power Systems



Source: Real Time Dynamics Monitoring System

Synchrophasor data streaming (PMUs)/México



Source: Centro Nacional de Control de Energía, México City

Reliable measurements: syntactic and semantic interoperability

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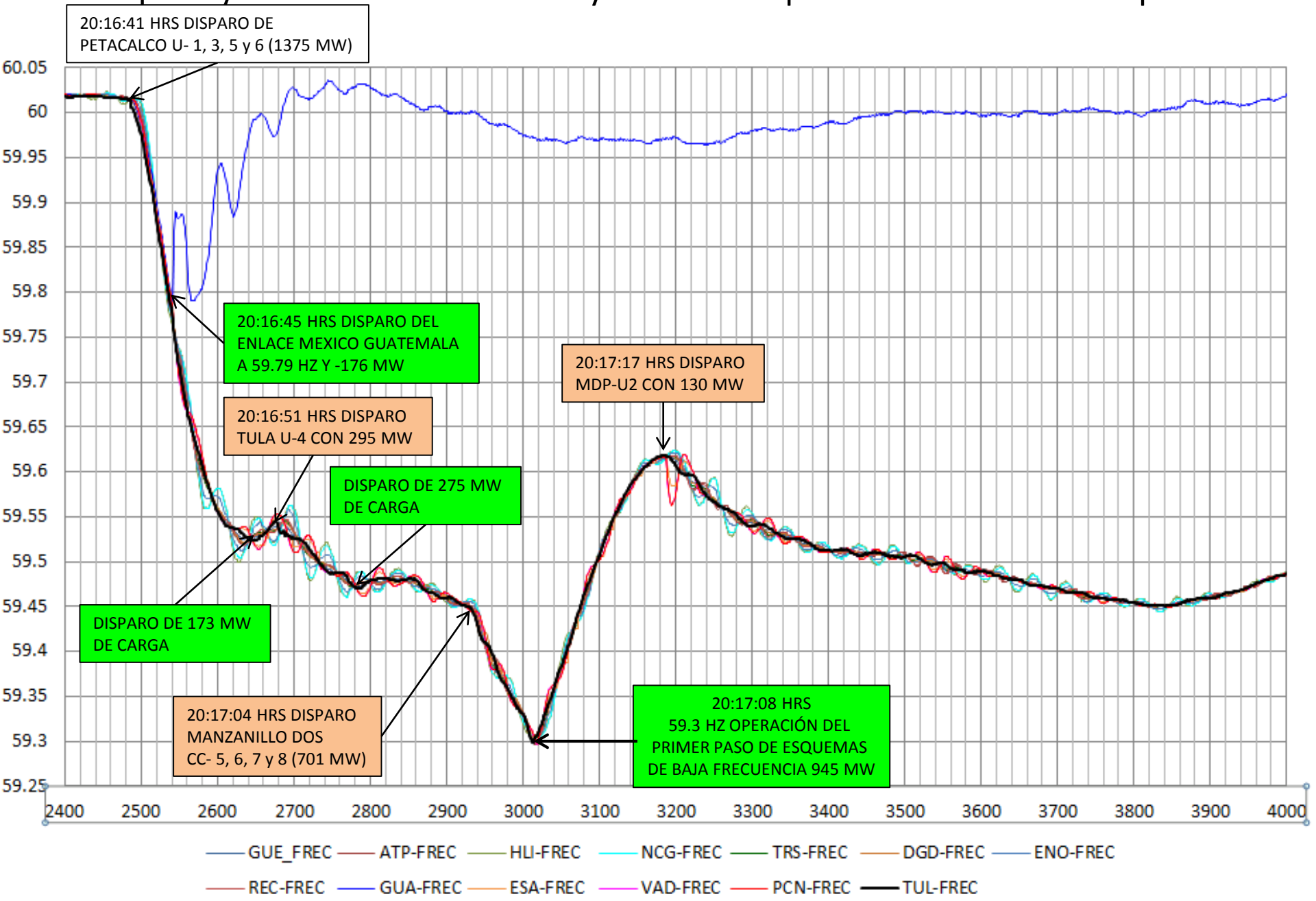
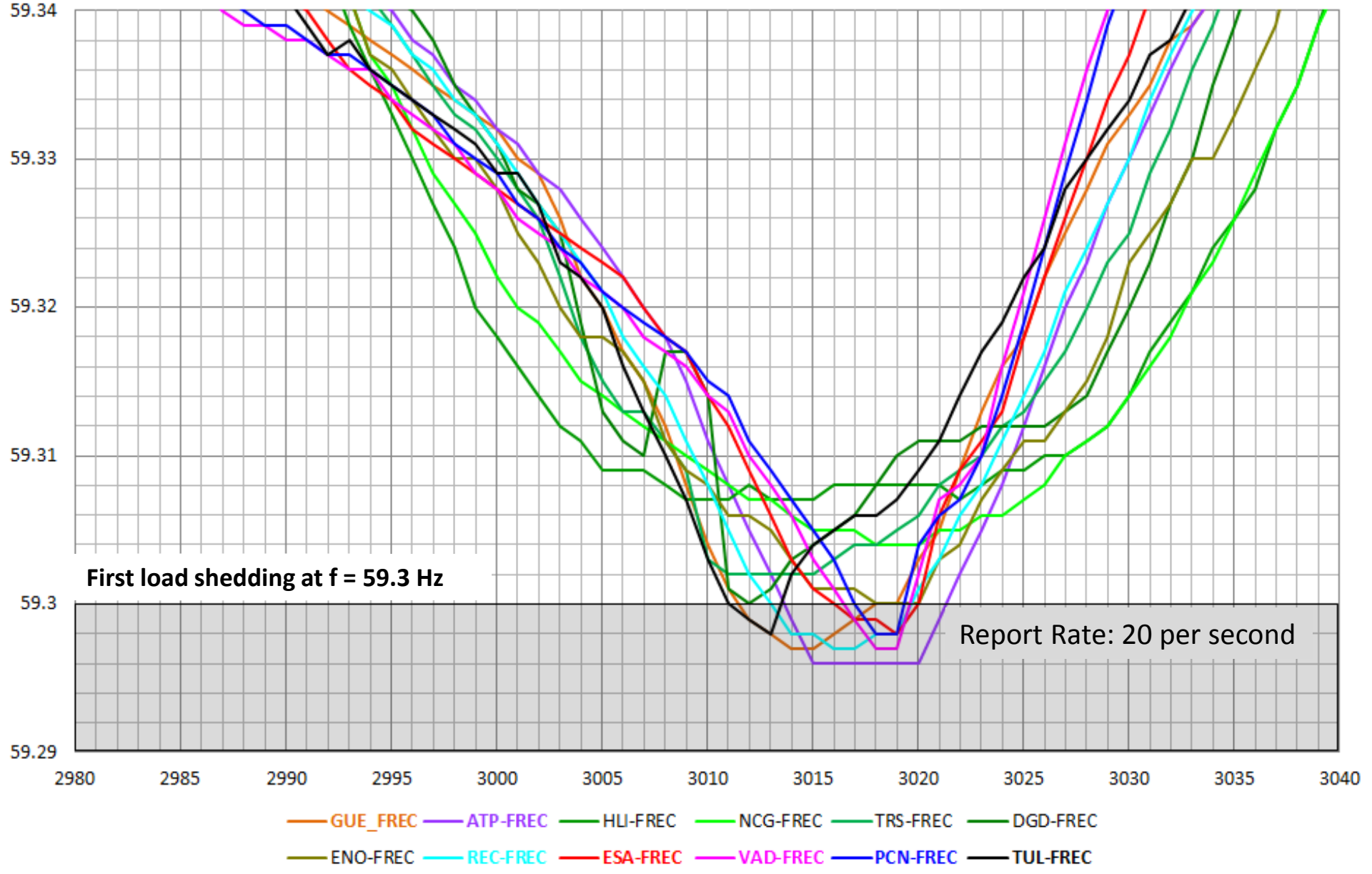
Operation of the under frequency scheme of the interconnected power system in México, 20:16:40. 21st April 2013

20:16:40, 21st APRIL 2013

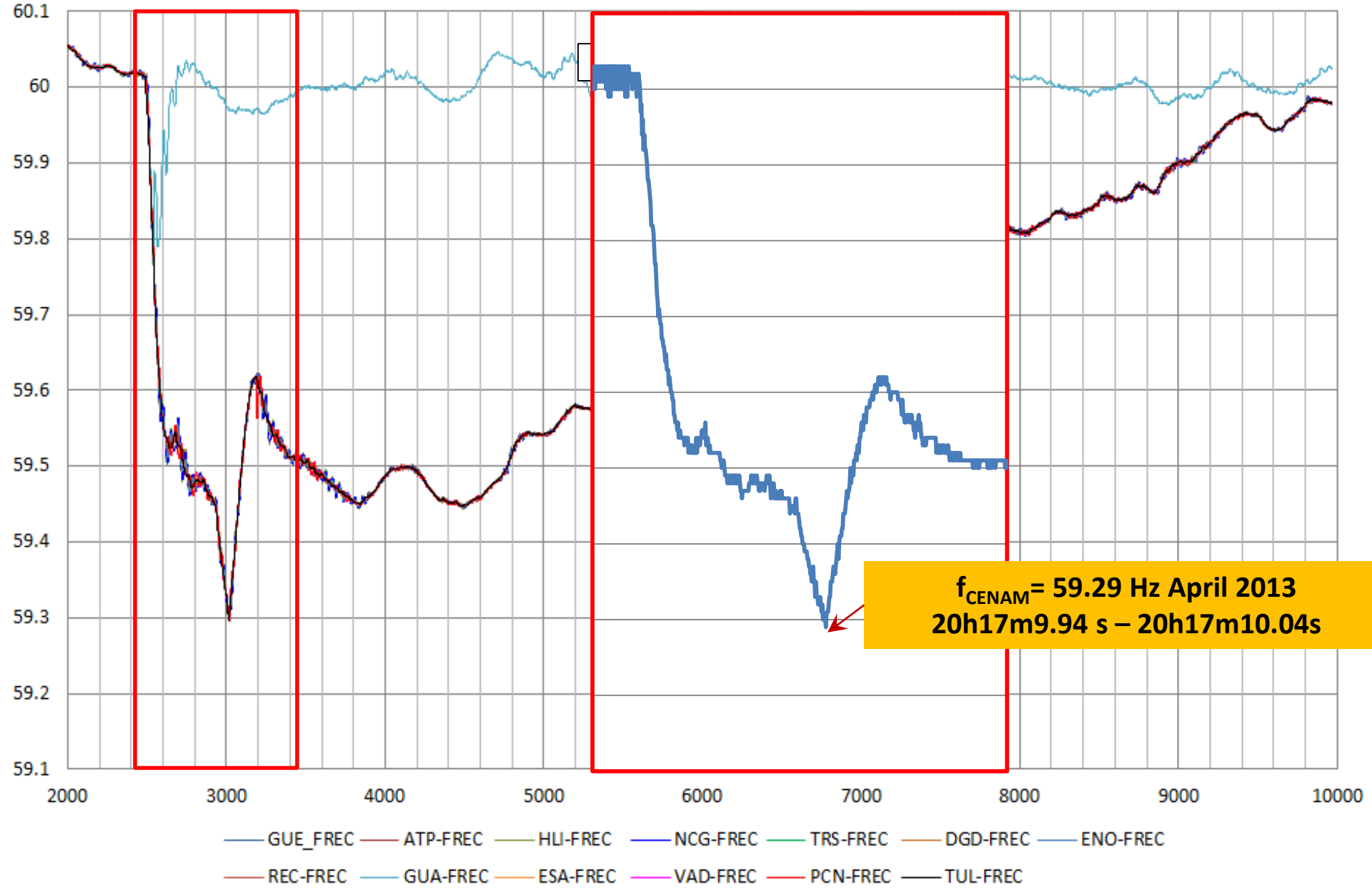
Frequency of the interconnected system. Earthquake 5.8 Richter. 21st April 2013



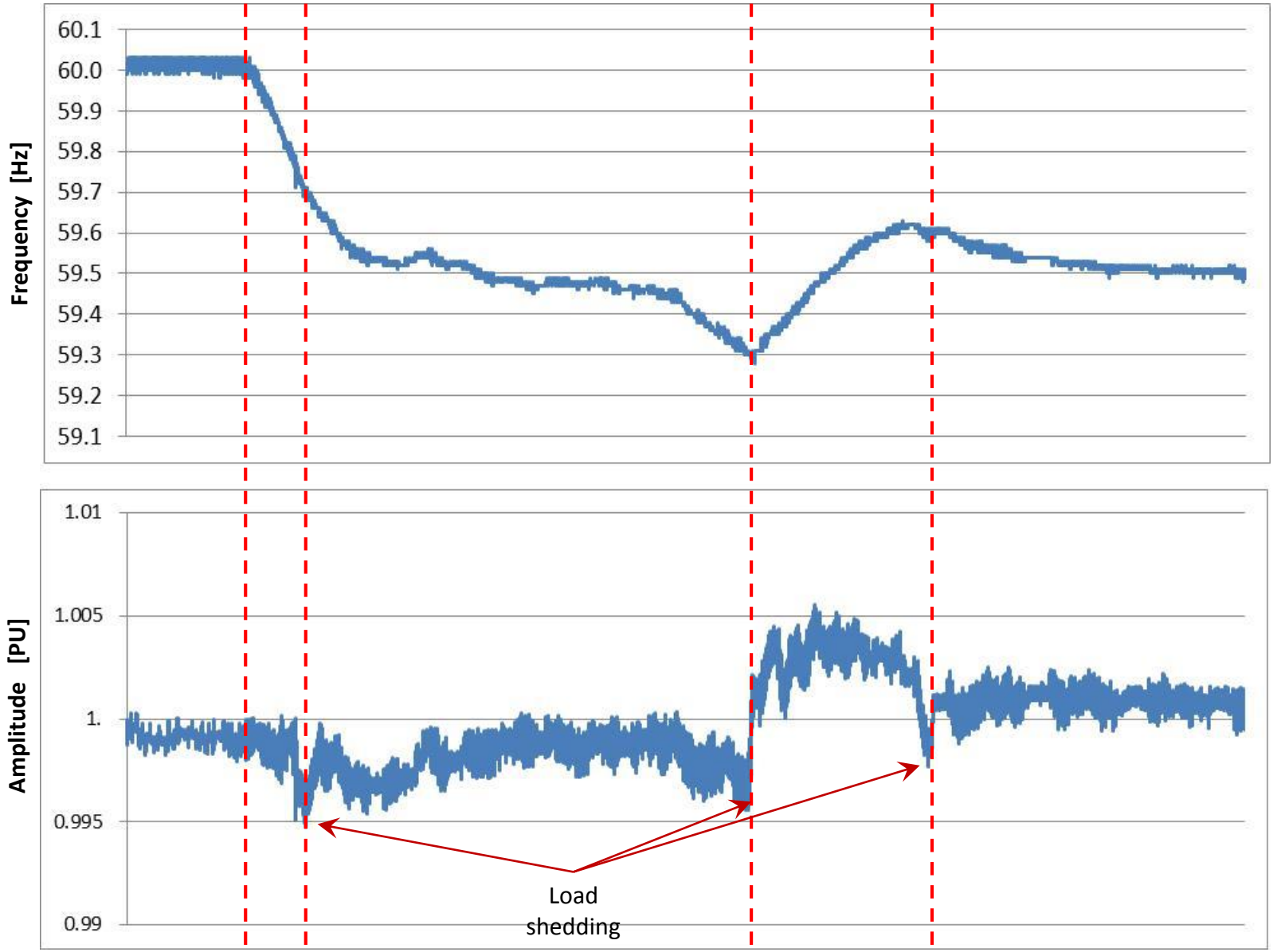
Frequency of the interconnected system. Earthquake 5.8 Richter. 21st April 2013



Measurements carried out by CENAM, 2014



Simultaneous measurement of amplitude and frequency/ CENAM



Authorized CFE-Transmisión-2014

Summary

- ✓ Compared to conventional generation (thermal power, hydropower, nuclear generation), renewable energies (wind, solar, geothermal) are much more uncertain.
- ✓ One important task of Smart Grid is to provide an interoperability infrastructure for free and safe interconnection of renewable energy generation to power systems.
- ✓ The main role of reliable measurements in Smart Grid is to ensure the syntactic and semantic interoperability as the base to communicate and exchange data, and to automatically interpret the exchanged data

Thanks

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rene.carranza@cenam.mx