Innovative local controls to improve grid stability

June 2010

tecnalia
Corporación Tecnológica

Index

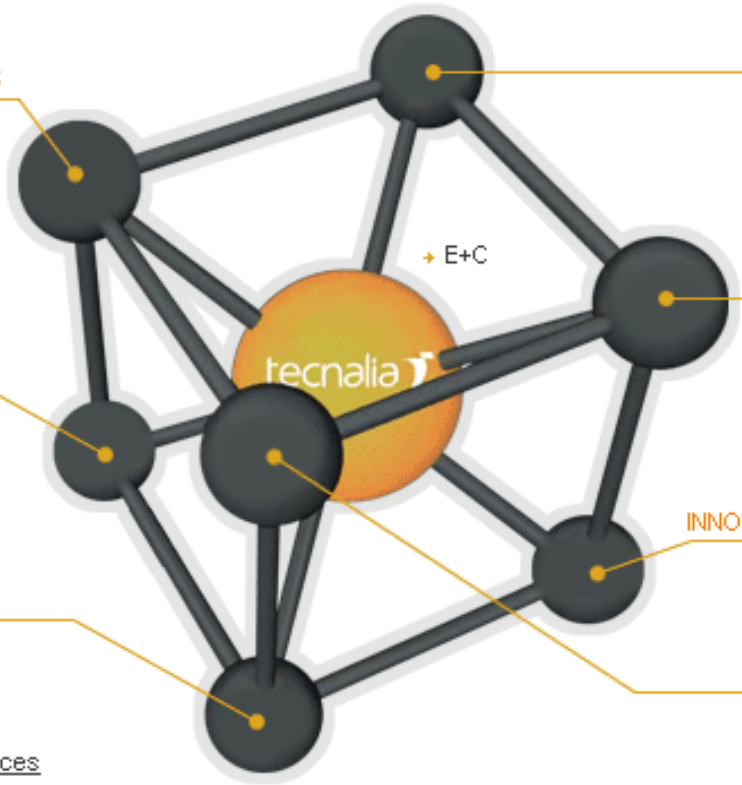
- Who are we?
- Why smartgrids?
- Nowadays situation
- Proinver project
- VSYNC project
  - Vsg requirements
  - Tecnalia proposed control system.
    - Tests and results
  - Vsync project demo sites
    - Cheia (Romania)
    - Bronsbergen (Nederland)

Who are we?

We are a private and independent Technological Corporationº integrated by the following centers:

AZTI, ESI, FATRONIK, INASMET, LABEIN, NEIKER y ROBOTIKER

20 Business Units



INFORMATION AND COMMUNICATION TECHNOLOGIES
- Infotech
- Information Society
- Software
- Telecom

INDUSTRIAL SYSTEMS AND PROCESSES
- Industrial Systems
- Iron & Steel
- Foundry

NATURAL RESOURCES
- Foodstuffs
- Agricultural Innovation
- Marine Research
- Environment and Natural Resources

HEALT AND QUALITY OF LIFE
- Health and Quality of Life
- Health

SUSTAINABLE DEVELOPMENT
- Energy
- Construction
- Urban and Industrial Environment

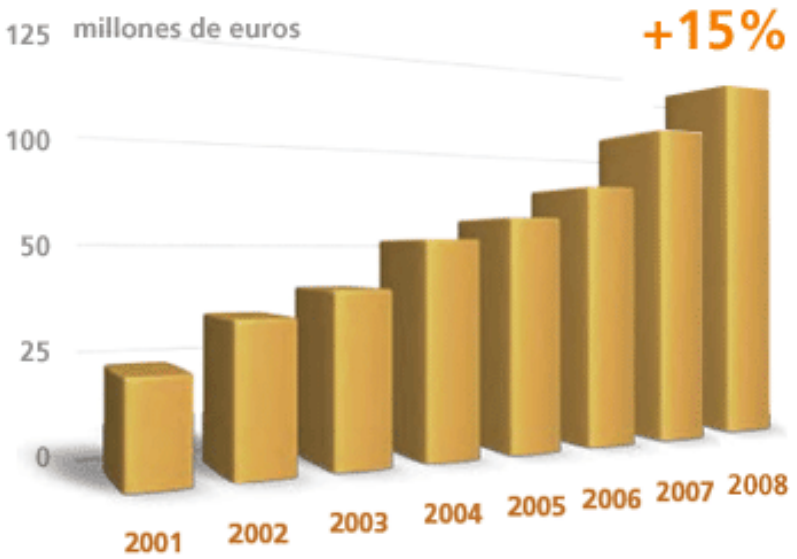
INNOVATION AND COMPETITIVENESS
- Innovation Systems

TRANSPORT AND MOBILITY
- Automotion
- Aerospace

1st Spanish Private technological corporation

→ *5th in Europe*

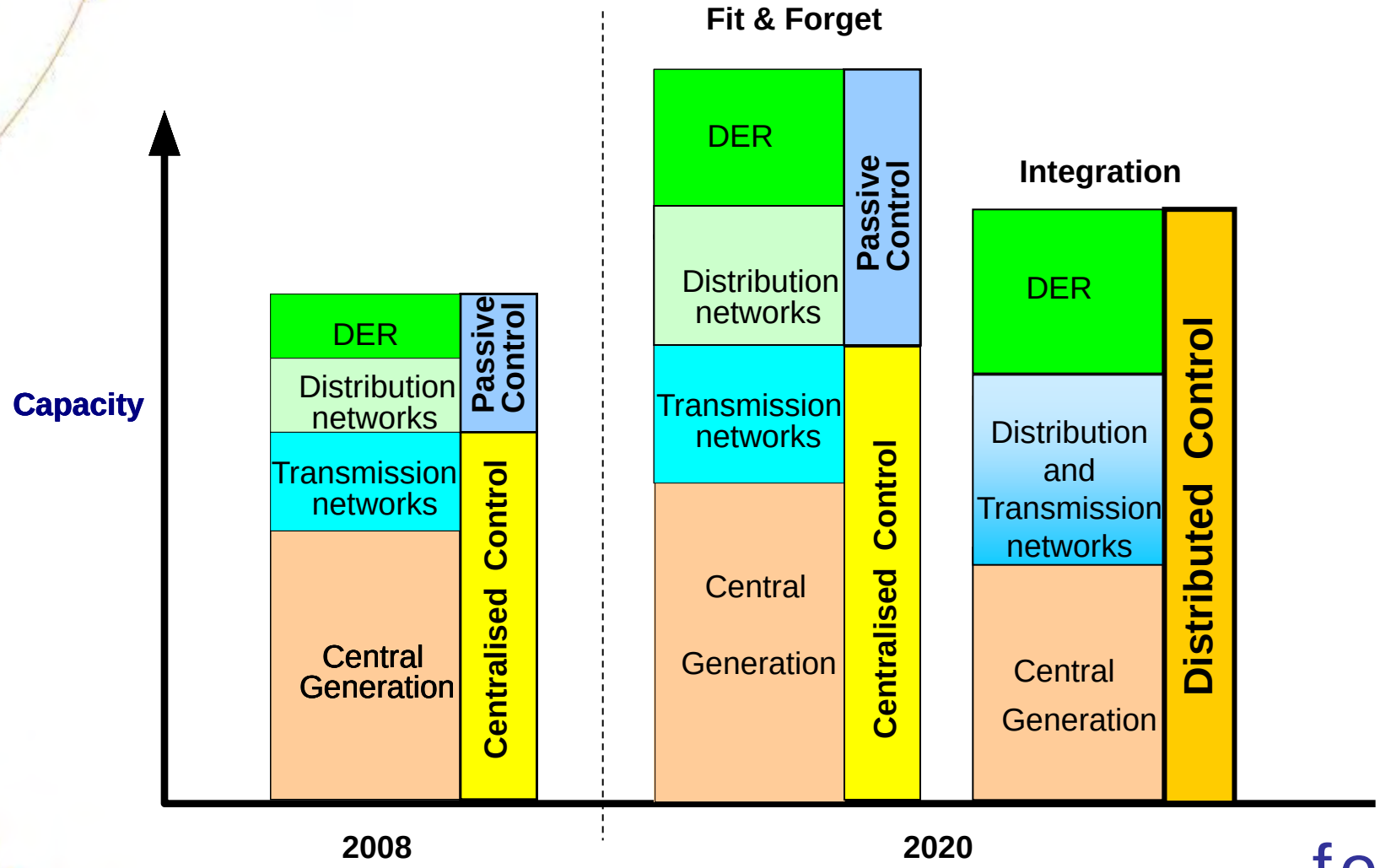
- *1.570 staff members*
- *3.235 clients*
- *20 patents*



Index

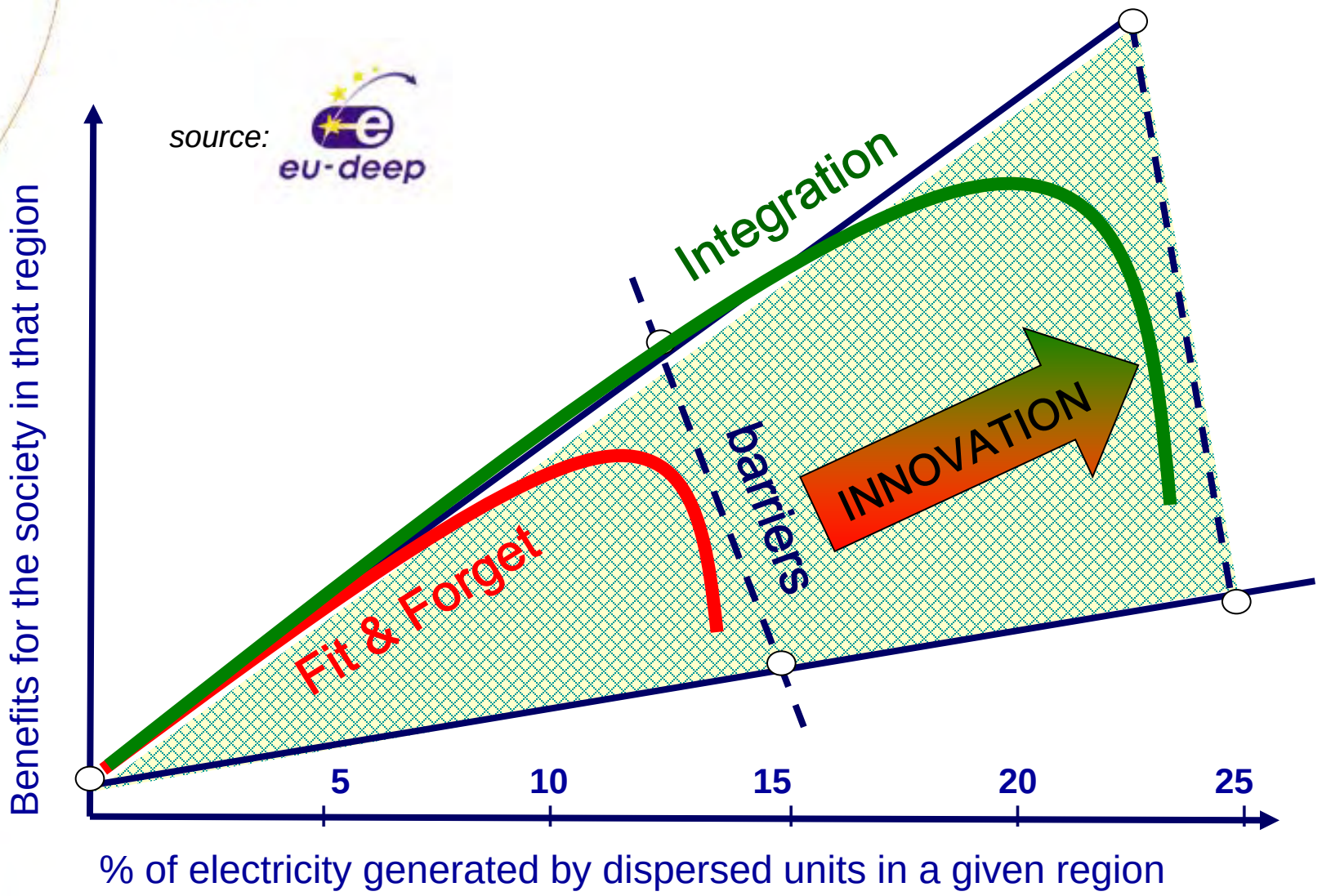
- **Who are we?**
- **Why smartgrids?**
- Actual situation
- Proinver project
- VSYNC project
  - Vsg requirements
  - Tecnalia proposed control system.
    - Tests and results
  - Vsync project demo sites
    - Cheia (Romania)
    - Bronsbergen (Nederland)

Why smart grids?



source: fenix '... a step towards the future of electricity networks'

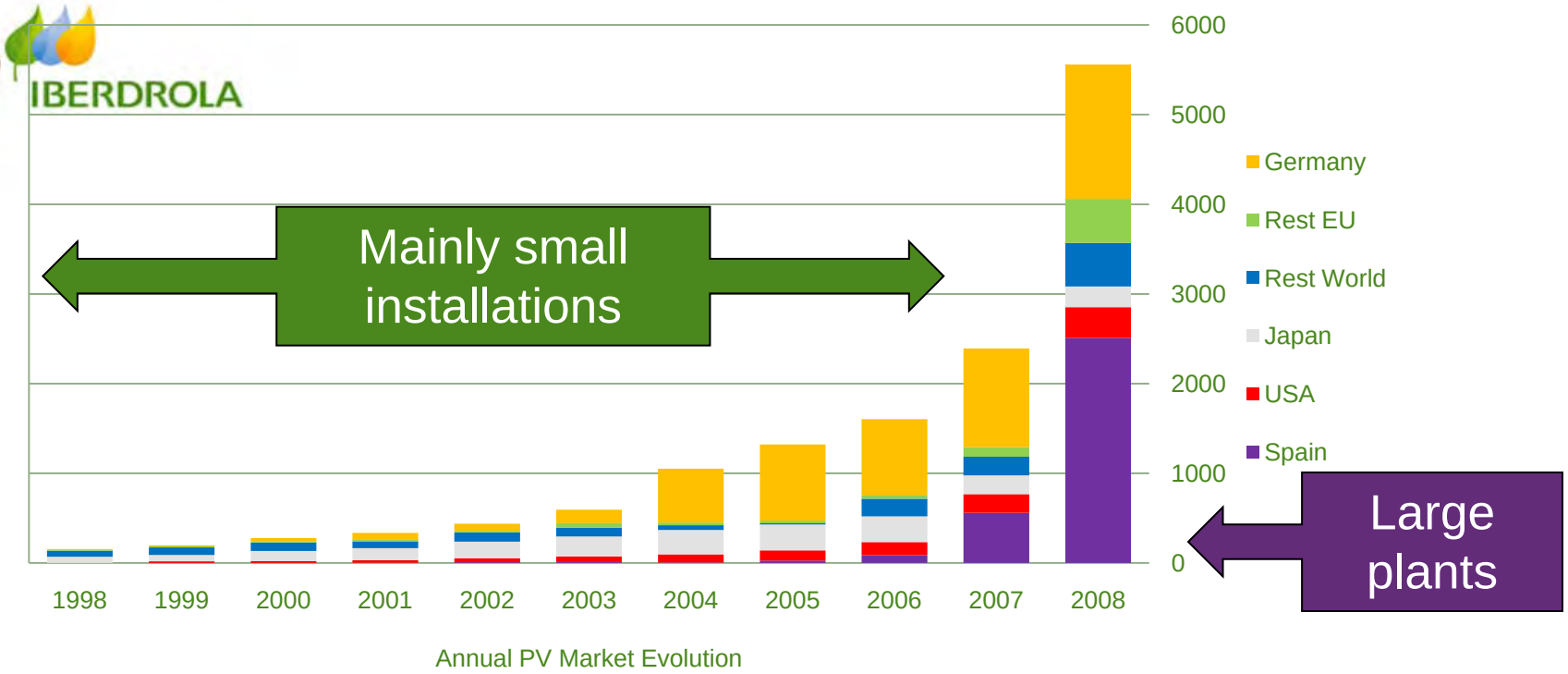
Why smart grids?



Index

- **Who are we?**
- **Why smartgrids?**
- **Actual situation**
- Proinver project
- VSYNC project
  - Vsg requirements
  - Tecnalia proposed control system.
    - Tests and results
  - Vsync project demo sites
    - Cheia (Romania)
    - Bronsbergen (Nederland)

Nowadays situation

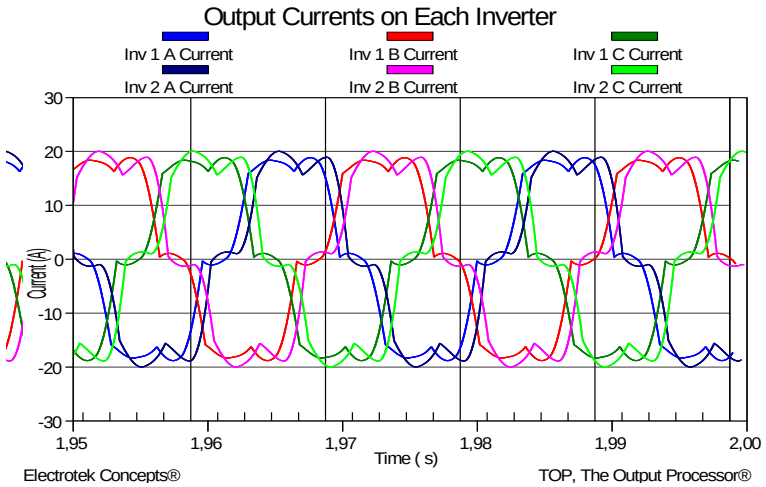


Annual PV Market Evolution

- The development of photovoltaic inverters is based in the principle that they are generators of a **irrelevant power** compared to the network.
- Most of the experience previous to the rapid growth of the PV generation in Spain, is related with **small installations**.
- In Spain, the same technology is applied to large plants, **without any adaptation**, reaching in many feeders a generation power that **exceeds** the load power.

Nowadays situation

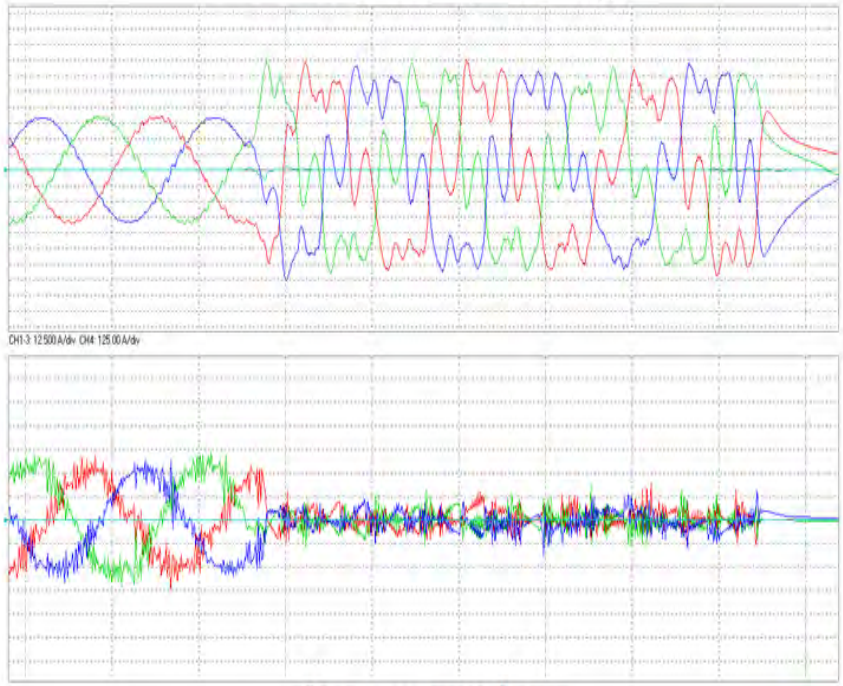
- The inverters are told not to **disturb** the network.
- They are **not** intended to share the **unbalanced** or the **harmonic** currents.
- All the unbalanced currents and harmonics should be fed by the **conventional grid** with a lower weight in the power generation.
- This strategy is **not longer possible** with a bigger DG penetration and growing non linear loads.



Nowadays situation

IBERDROLA

ON SITE TEST IN LARGE PV PLANTS
LV switch opening



2 p.u. overvoltage

PAZOS-Spain Session 4 Paper 0159

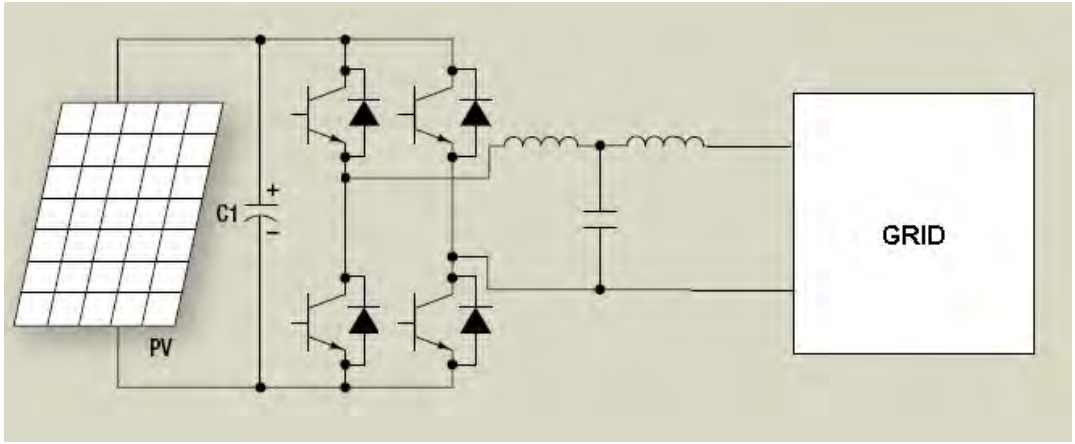
IBERDROLA

- **Damages** due to over voltages detected by Iberdrola in 2008, but known by some manufacturers some years before.
  - **All** inverters produce overvoltages, but in some manufacturers the magnitude and duration are enough to damage other devices:
    - Revenue meters
    - Occasionally control devices
- An **improvement** enough to prevent damages was identified and implemented by some manufacturers
- **Communicated** by Iberdrola to PV associations, manufacturers, standardization bodies and published in conferences.

Index

- **Who are we?**
- **Why smartgrids?**
- **Actual situation**
- **Proinver project**
- VSYNC project
  - Vsg requirements
  - Tecnalia proposed control system.
    - Tests and results
  - Vsync project demo sites
    - Cheia (Romania)
    - Bronsbergen (Nederland)

- **PROINVER** project is being pushed by **Iberdrola** to define new behaviors in the grid connected inverters
- The project involves **research centers, laboratories, manufacturers**.
- The aim of the project is:
  - To define working **anti islanding** protection.
  - To **avoid** the **damages** caused by the inverters during non intentional islanding.
  - To establish the mechanism for the **intentional islanding**.
  - To define the needed behavior of the inverters to **collaborate** with the grid (harmonics, unbalance, stability …)



Index

- **Who are we?**
- **Why smartgrids?**
- **Actual situation**
- **Proinver project**
- **VSYNC project**
  - Vsg requirements
  - Tecnalia proposed control system.
    - Tests and results
  - Vsync project demo sites
    - Cheia (Romania)
    - Bronsbergen (Nederland)

Vsync Project

Consortium:

ECN (coordinator) (NL)

Technical University Eindhoven (NL)

Delft University of Technology (NL)

Catholic University of Leuven (BE)

Polytechnics University of Bucharest (RO)

TECNALIA (ES)

3E (BE)

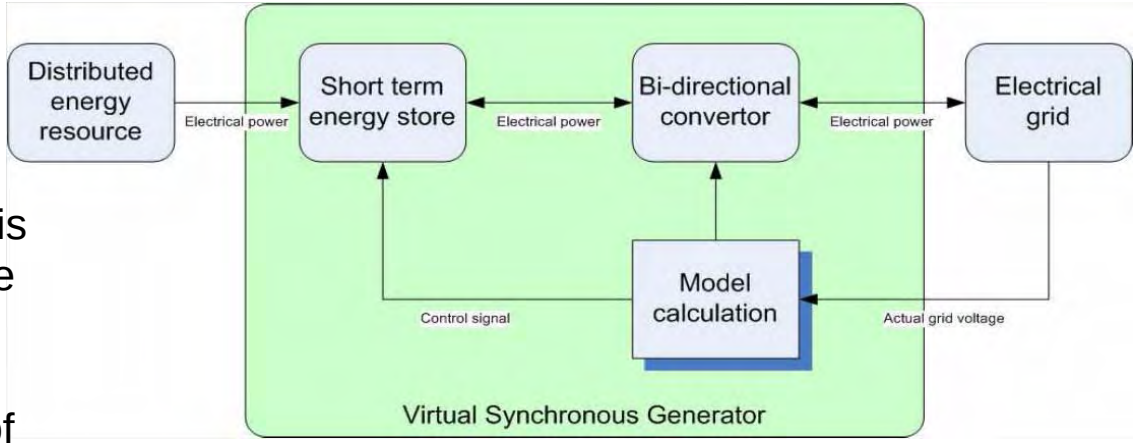
UfE (D)

Electrica. S.A. (RO)

Liander (NL)

http://www.vsync.eu

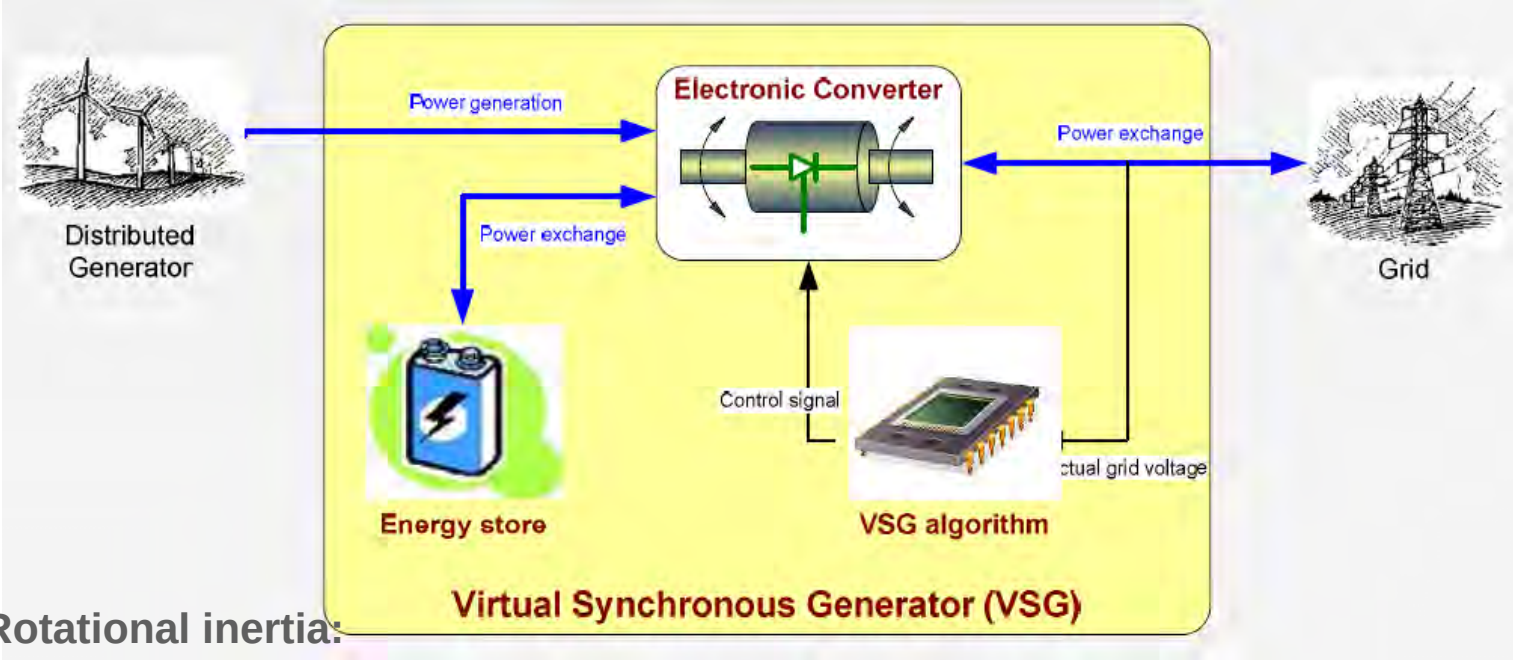
- **Virtual Synchronous Machines** (VSG's) For Frequency Stabilisation In Future Grids With A Significant Share Of Decentralized Generation.
- Problem definition
  - In electricity grids the **frequency** of the voltage is stabilized by a combination of the **rotational inertia** (rotating mass) and a control algorithm acting on the rotational speed of a number of major synchronous power generators. In future the total **rotational inertia** of the synchronous generators is **decreased** significantly. This causes large **frequency variations**.
- Solution
  - A way to stabilize the grid frequency is to add **virtual rotational inertia** to the distributed generators. In this way a generator can behave like a "Virtual Synchronous Generator" (VSG) and **contribute** to stabilization of the grid frequency.



Index

- **Who are we?**
- **Why smartgrids?**
- **Actual situation**
- **Proinver project**
- **VSYNC project**
  - **Vsg requirements**
  - Tecnalia proposed control system.
    - Tests and results
  - Vsync project demo sites
    - Cheia (Romania)
    - Bronsbergen (Nederland)

Vsync Project: VSG requirements



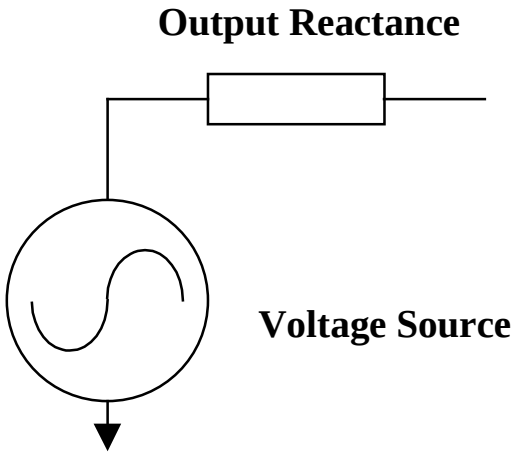
- **Rotational inertia:**
  - Helps in the **stability** of the frequency. Avoid the changes in the frequency.
- **Power control:**
  - Takes the frequency to the **desired values**.
- **Voltage Control:**
  - Takes the **voltage magnitude** to the desired values
- **Short-circuit behaviour:**
  - Feeds the faults ¿really necessary?

Index

- **Who are we?**
- **Why smartgrids?**
- **Actual situation**
- **Proinver project**
- **VSYNC project**
  - **Vsg requirements**
  - **Tecnalia proposed control system.**
    - Tests and results
  - Vsync project demo sites
    - Cheia (Romania)
    - Bronsbergen (Nederland)

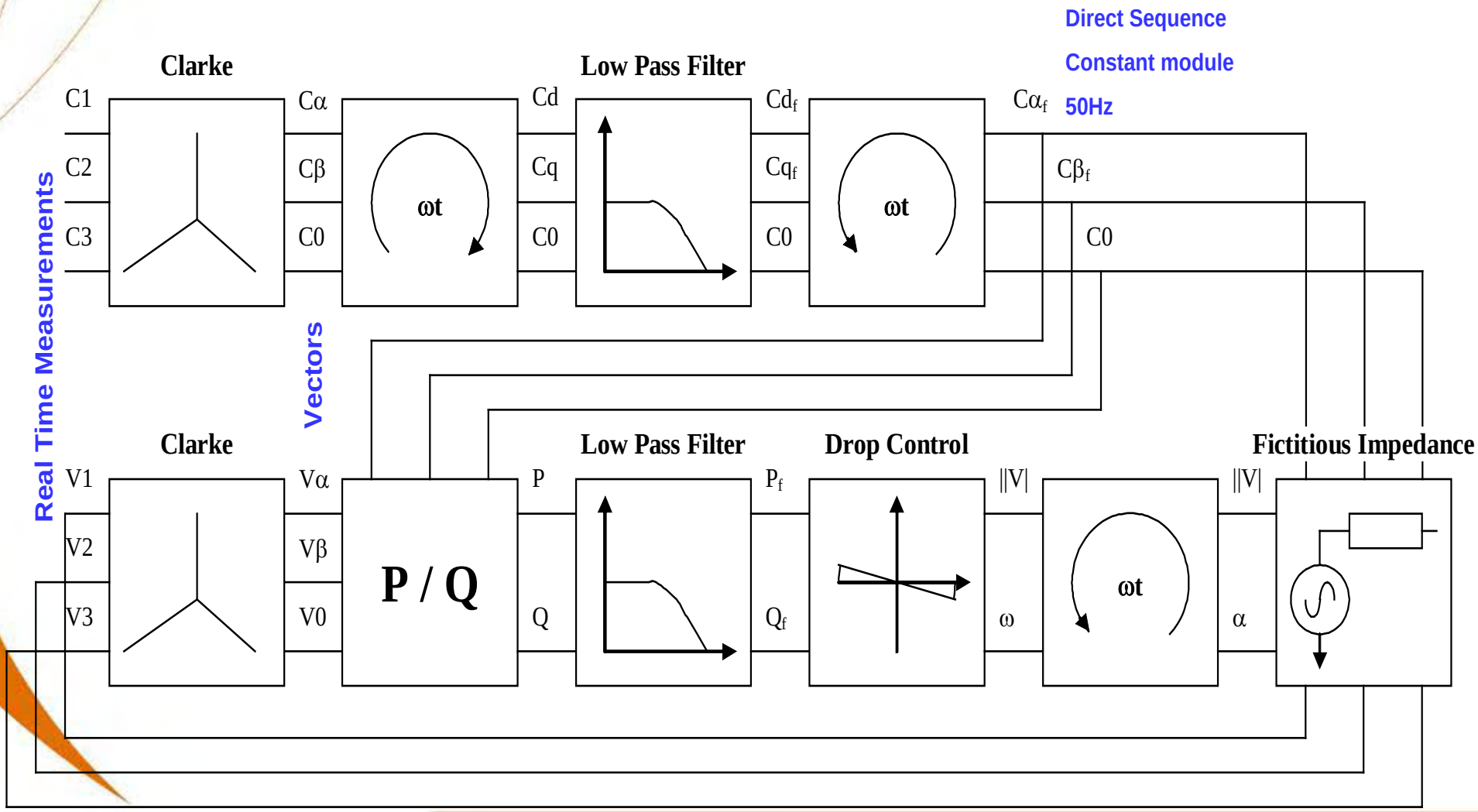
Vsync Project: Proposed control system

- Inverters acting as a **VOLTAGE SOURCE**.
- Bigger system stability.
- **Share** in the active and reactive power generation, harmonics, unbalanced loads.
- **Not very accurate** measurement of the frequency needed.
- **Faster** response to grid changes.
- The system behaves as a **inductive coupled** system.
- With this scheme the **sharing of the balanced** loads is assured.
- For the sharing of the unbalanced loads and harmonics an additional **fictitious resistance** is simulated. The no direct sequence current flow across this resistance.
- The Low-Pass filters affect the stability and the **dynamic** performance.



Vsync Project: Proposed control system

- Proposed control system:



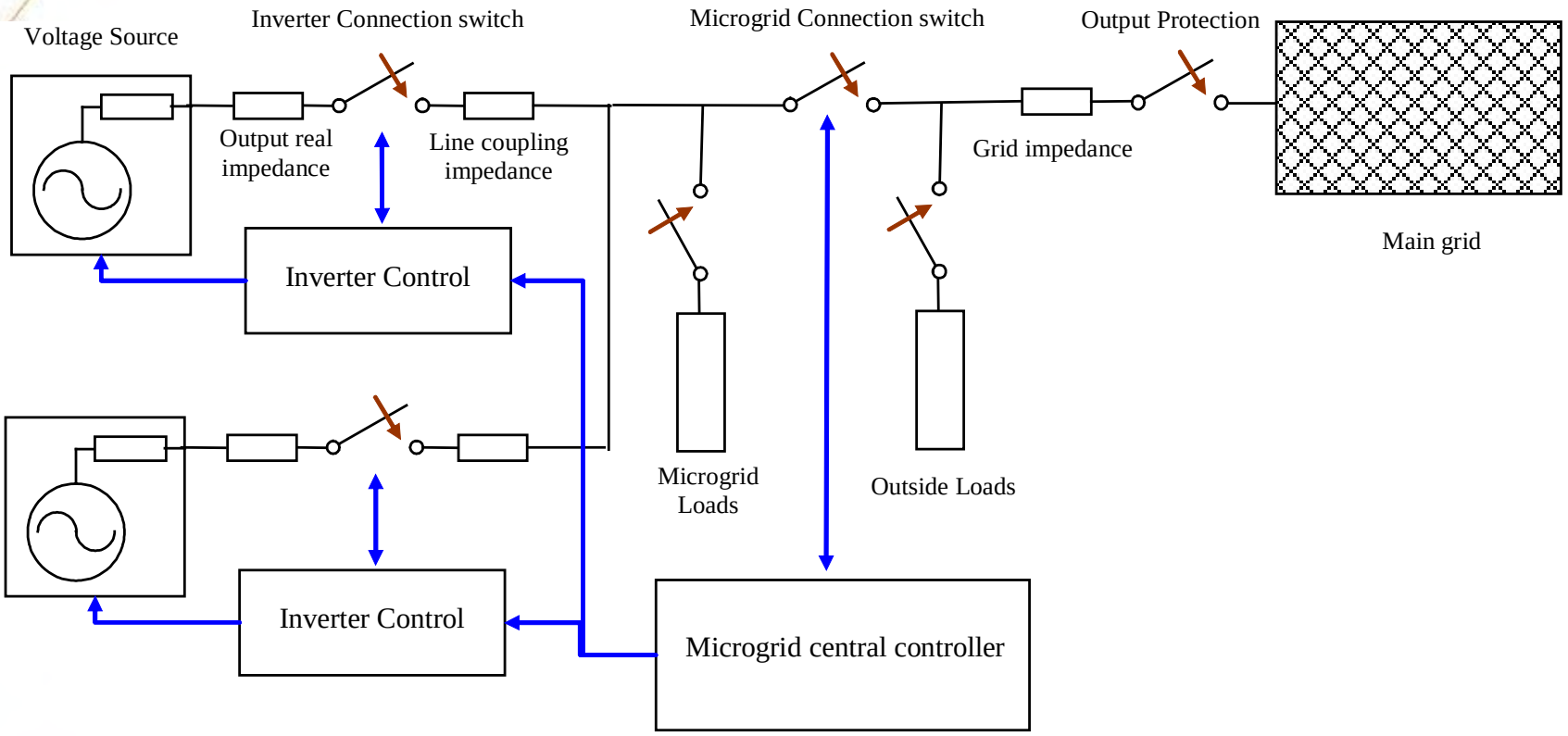
Vsync Project: Proposed control system

- Initially the currents are **measured** and filtered.
- Then according with the output voltage the **active and reactive power are calculated**.
- Powers are **filtered** to smooth the response of the inverter.
- Frequency and Voltage **Drops** are applied.
- **Output impedance** is simulated. Inductive for the positive sequence current and resistive for the rest.

Index

- **Who are we?**
- **Why smartgrids?**
- **Actual situation**
- **Proinver project**
- **VSYNC project**
  - **Vsg requirements**
  - **Tecnalia proposed control system.**
    - **Tests and results**
  - Vsync project demo sites
    - Cheia (Romania)
    - Bronsbergen (Nederland)

Vsync Project: Simulation and Test layout

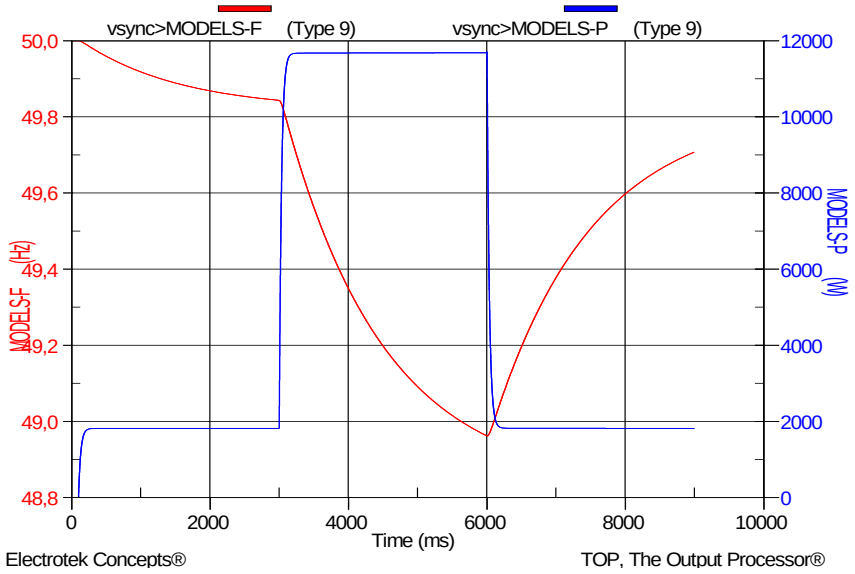


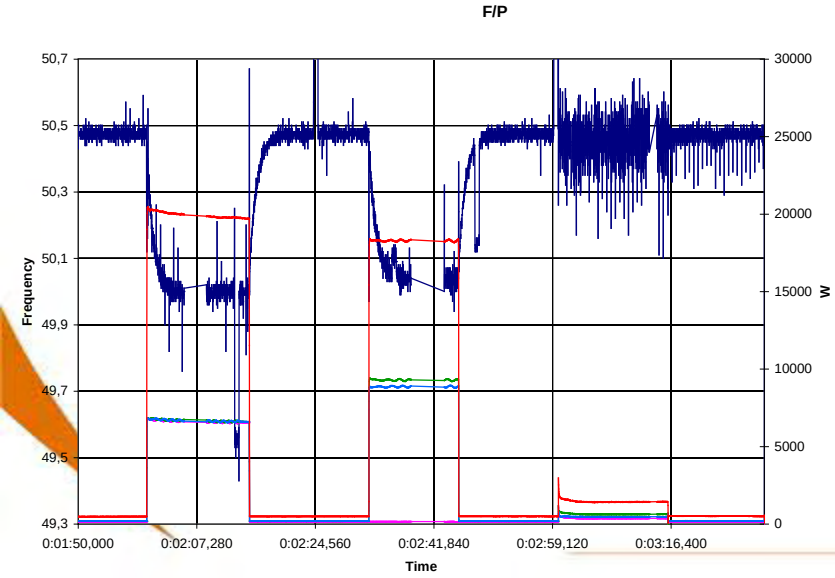
Proposed control system: Rotational Inertia

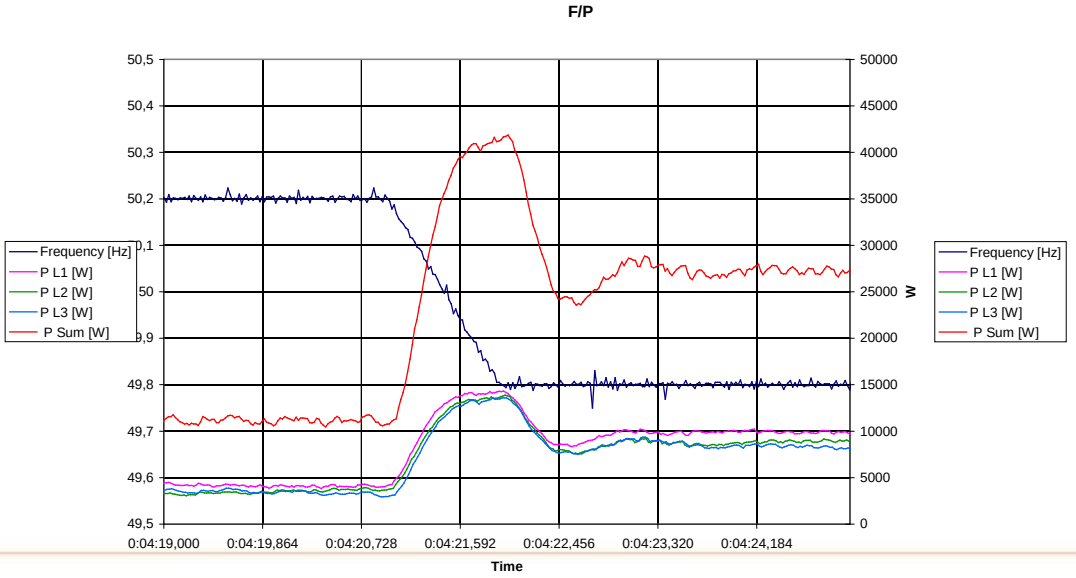
- Rotational Inertia

$$P_{VSGreq,ic} = -pJ_{SG}\omega_{gr}\frac{d\omega_{gr}}{dt}$$

$$P_{VSGprop,ic} = -\frac{k}{\omega_{cP}}\frac{d\omega_{gr}}{dt}$$







Proposed control system: Power Control

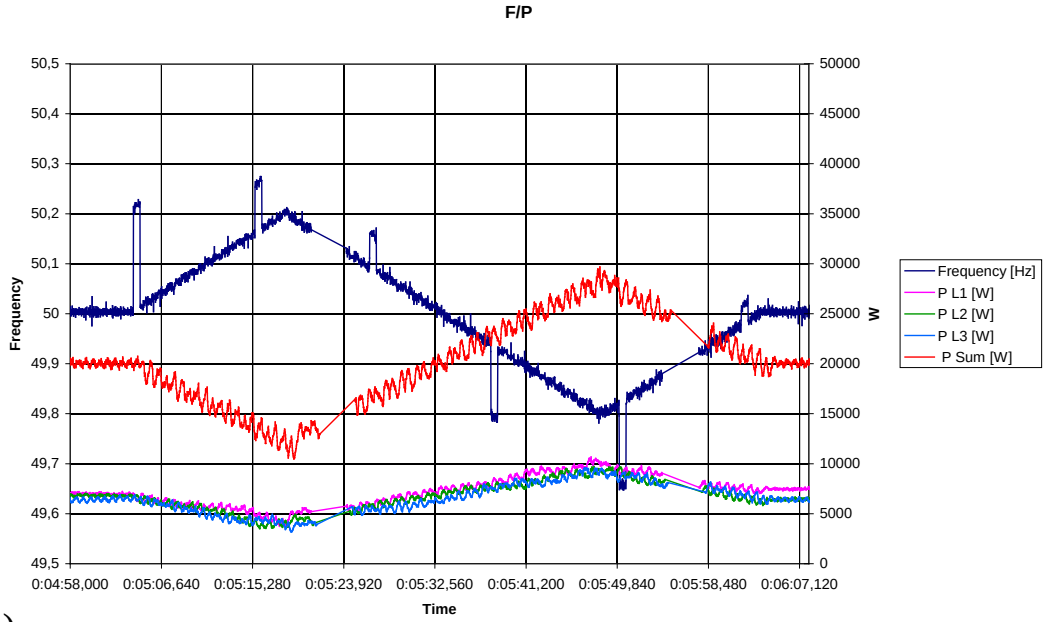
- Power Control

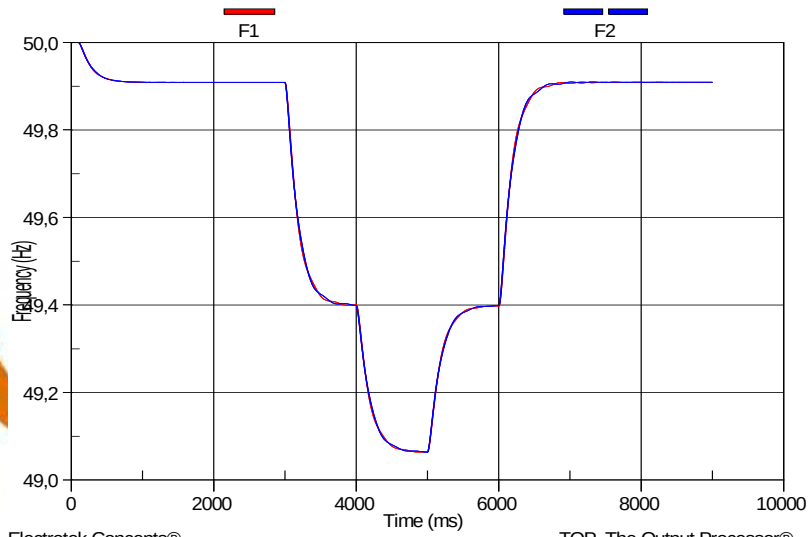
$$\omega_{VSG} = \omega_{gr,ref} - \frac{1}{k}(P_{VSG,pc} - P_{ref})$$

  - Achieved by the drop control
  - A term depending on the SOC of the storage should be added

$$P_{VSG,pc} = P_{ref} - k_{\omega}(\omega_{gr} - \omega_{gr,ref}) + k_{soc}(soc - soc_{ref})$$

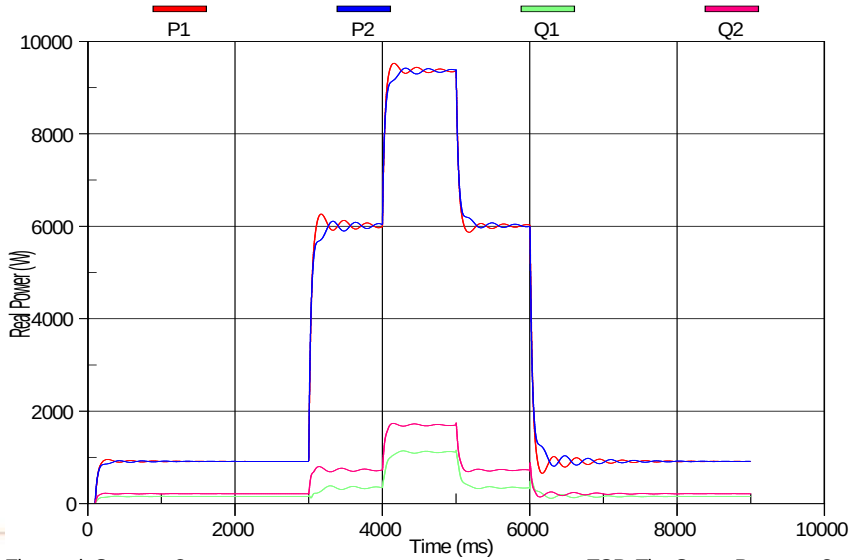
$$\omega_{VSG} = \omega_{gr,ref} - \frac{1}{k_{\omega}}(P_{VSG,pc} - P_{ref}) + \frac{k_{soc}}{k_{\omega}}(soc - soc_{ref})$$





Electrotek Concepts®

TOP, The Output Processor®

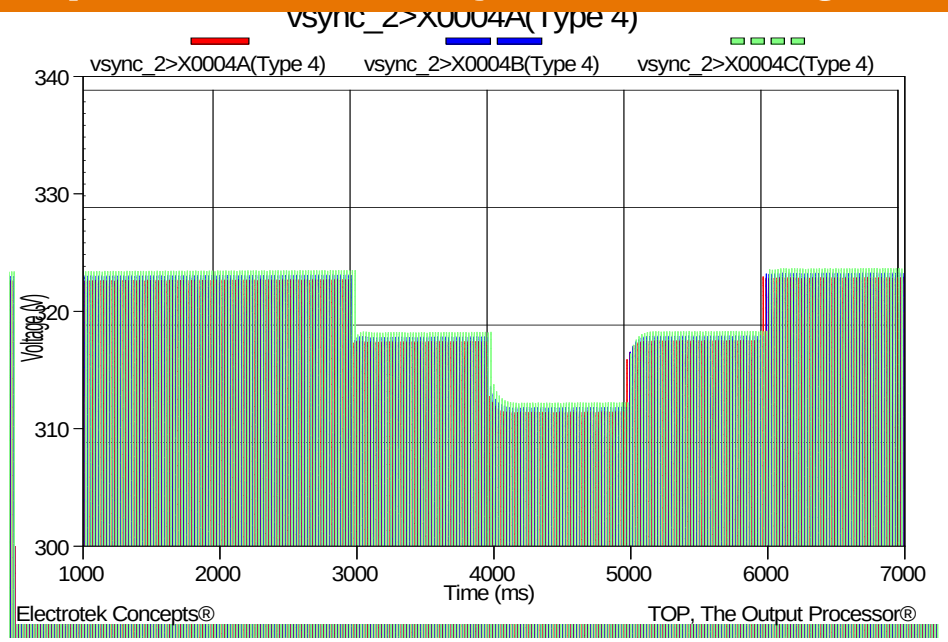


Electrotek Concepts®

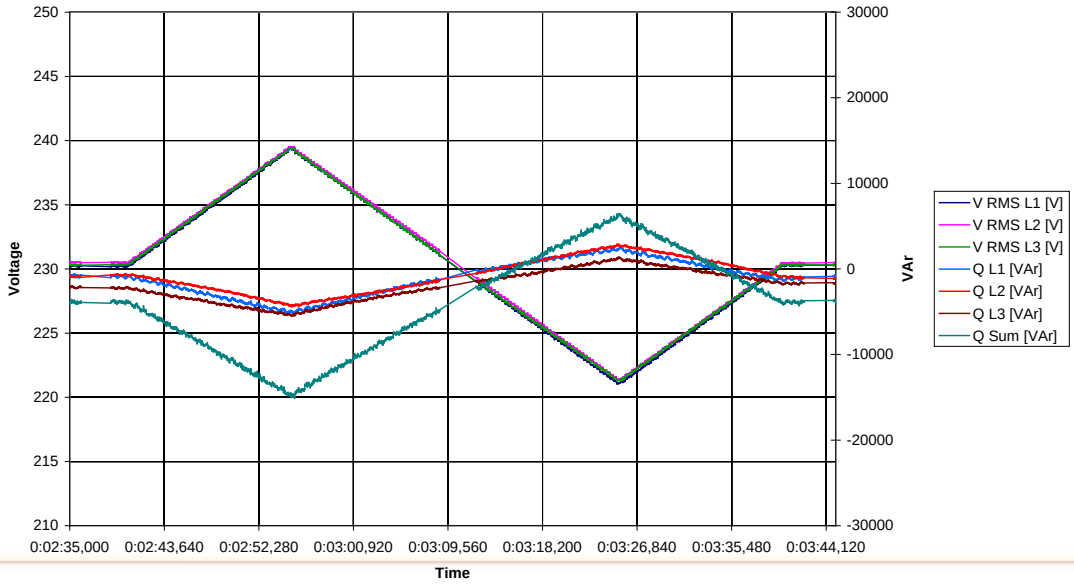
TOP, The Output Processor®

Proposed control system: Voltage Control

- Voltage Control
  - Achieved by the drop control and the fictitious impedance
  - The reactive power consumption is shared among the closest VSGs.
  - The voltage depends on the reactive consumption

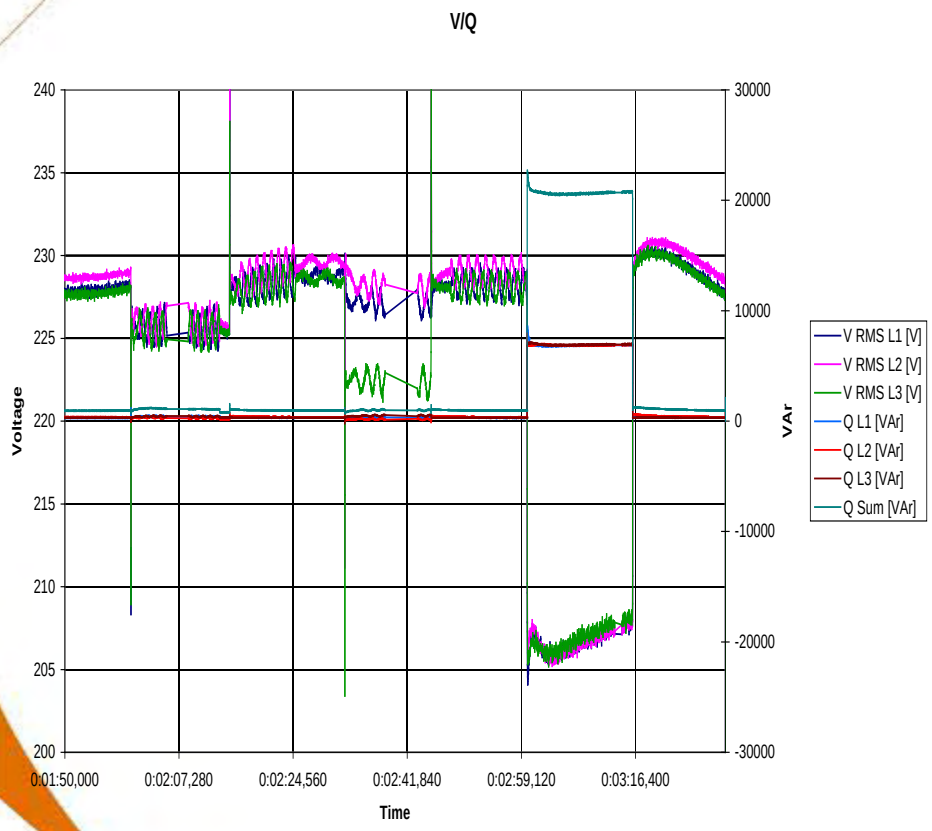


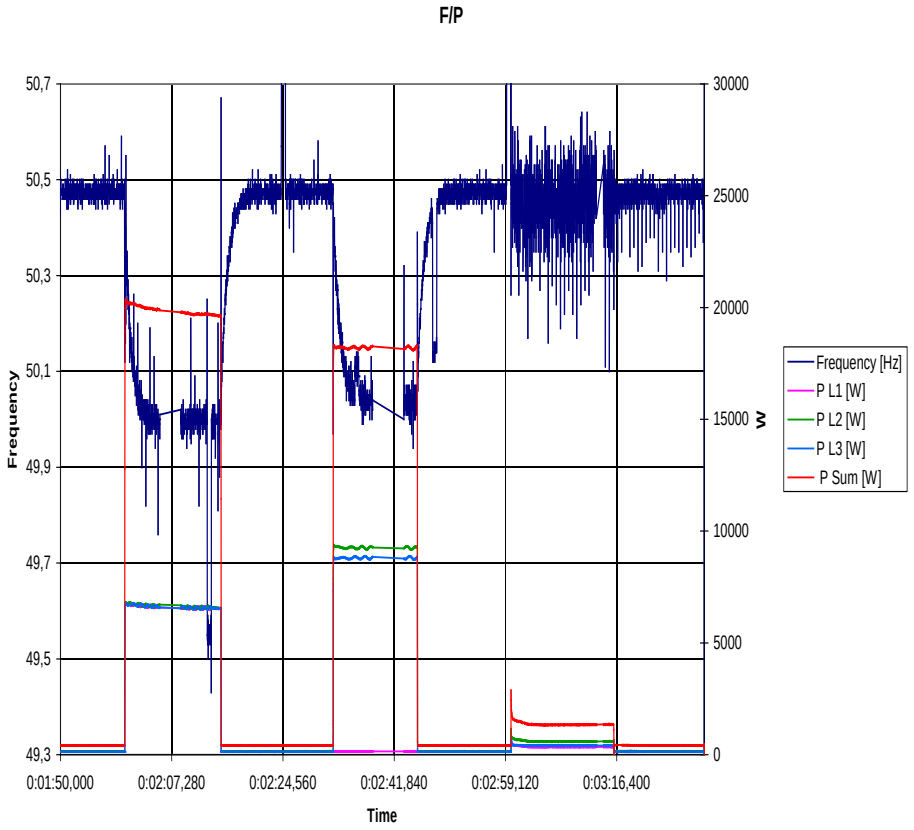
V/Q



Proposed control system: Island Behaviour

- Island Behaviour





Index

- Who are we?
- Why smartgrids?
- Actual situation
- Proinver project
- VSYNC project
  - Vsg requirements
  - Tecnalia proposed control system.
    - Tests and results
  - Vsync project demo sites
    - Cheia (Romania)
    - Bronsbergen (Nederland)

- **Romania Field Test**
  - Located in Cheia (Romania)
    - Remote grid with power quality problems
  - 1*90KVA VSG Installed
- **Nederland Field Test**
  - Located in Bronsbergen (Romania)
    - Experimental real microgrid with a lot of DER
  - 1*90KVA VSG Installed
  - 10*5KVA VSG Installed

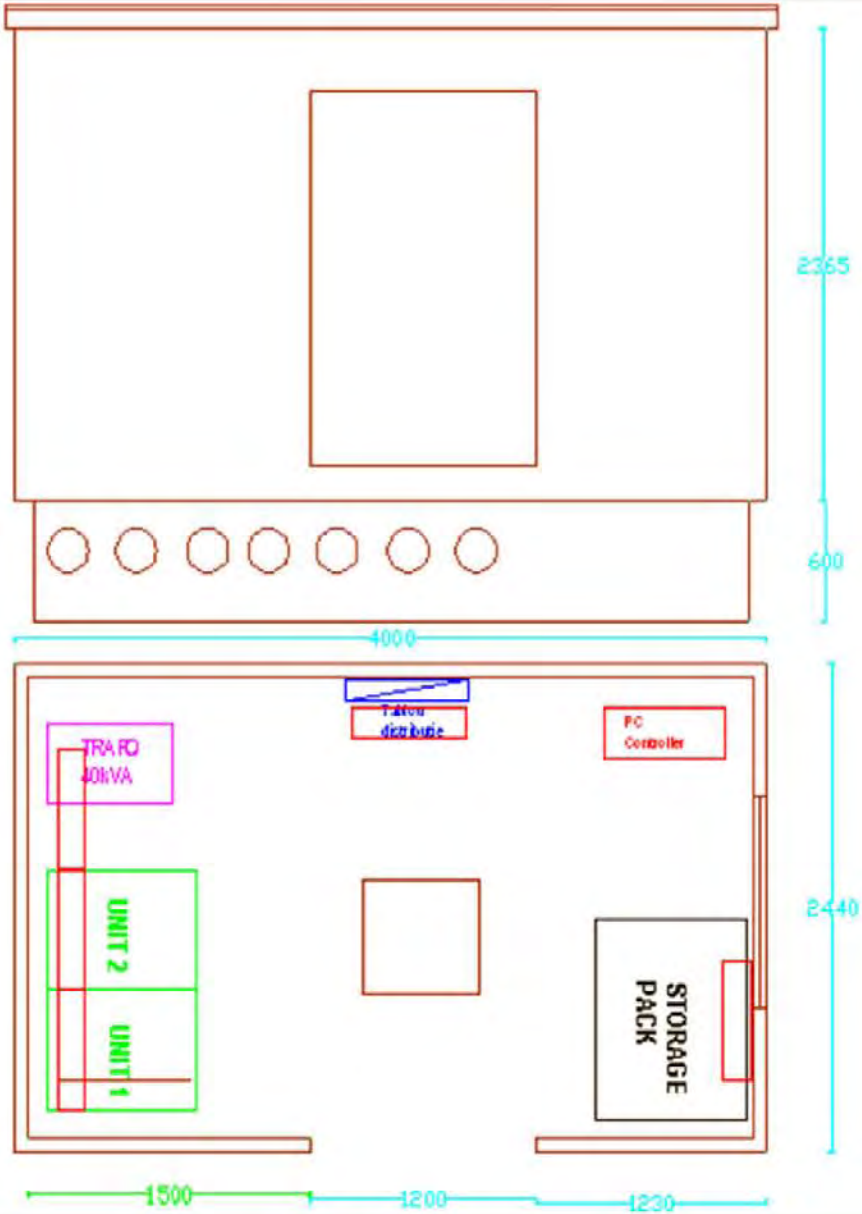
Cheia field test – data acquisition, communication and control

Dumitru Federenciuc, Electrica SA

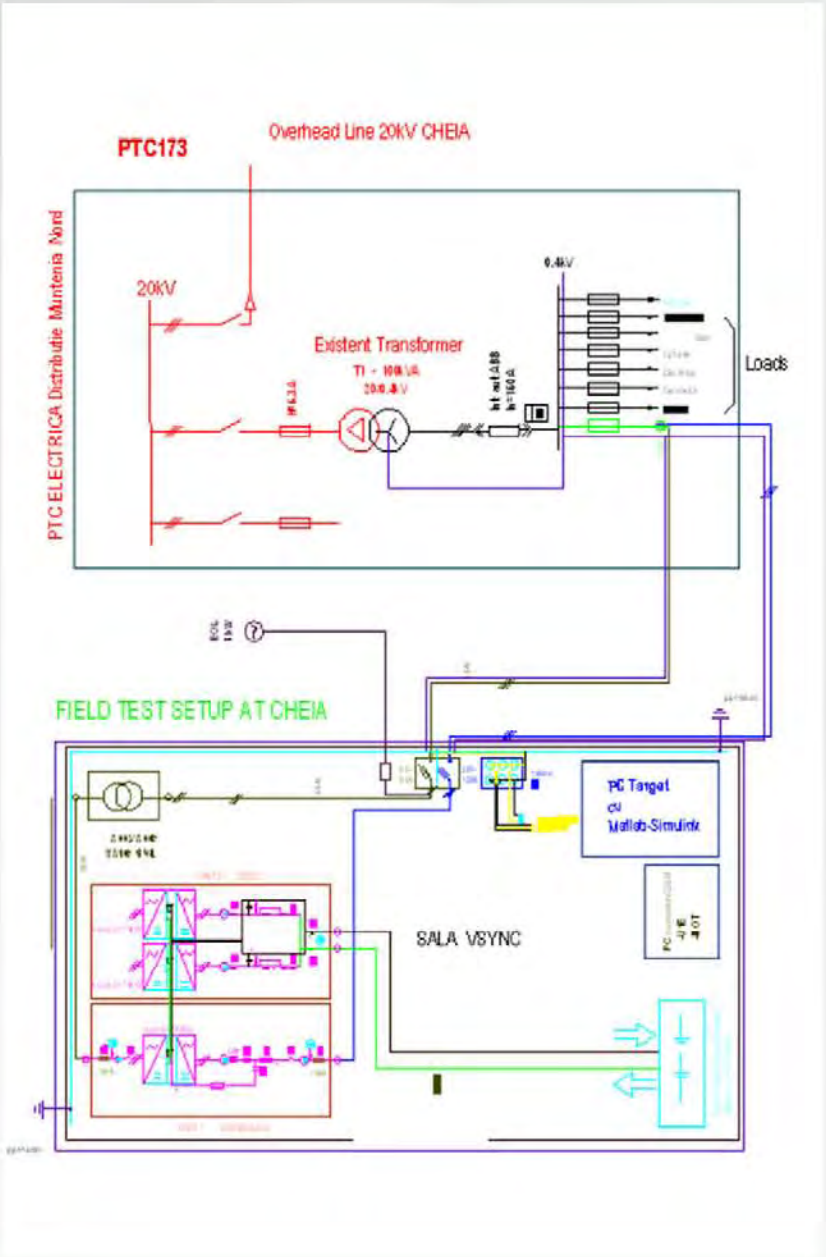
Mihaela Albu, "Politehnica" University of Bucharest

Fieldtest equipment at Cheia, Romania

triphase

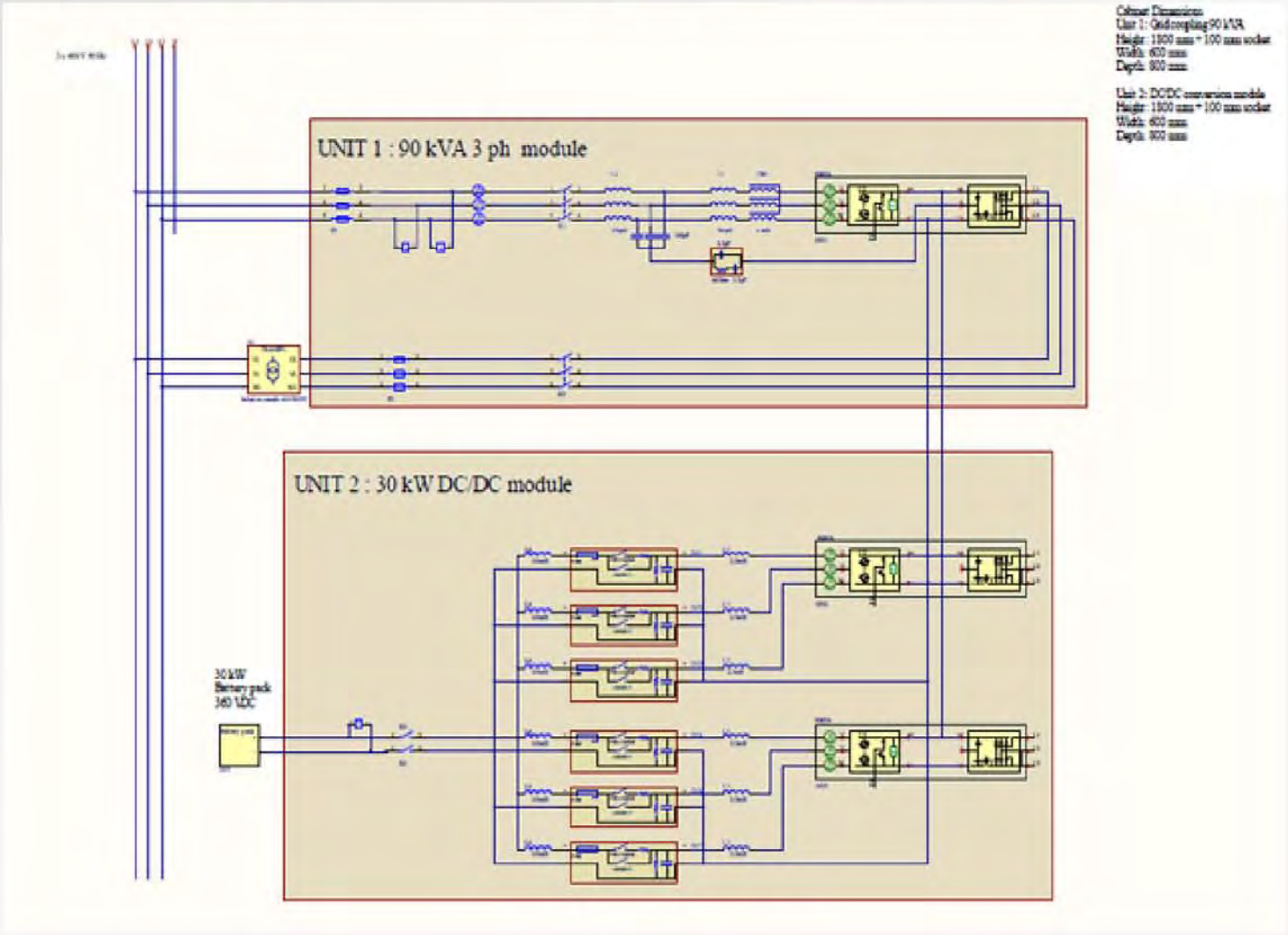


Layout of the equipment in the concrete house



Electrical Diagram of the equipment to be used during the field test at Cheia, Romania

Power section of the Triphase equipment (90kVA)



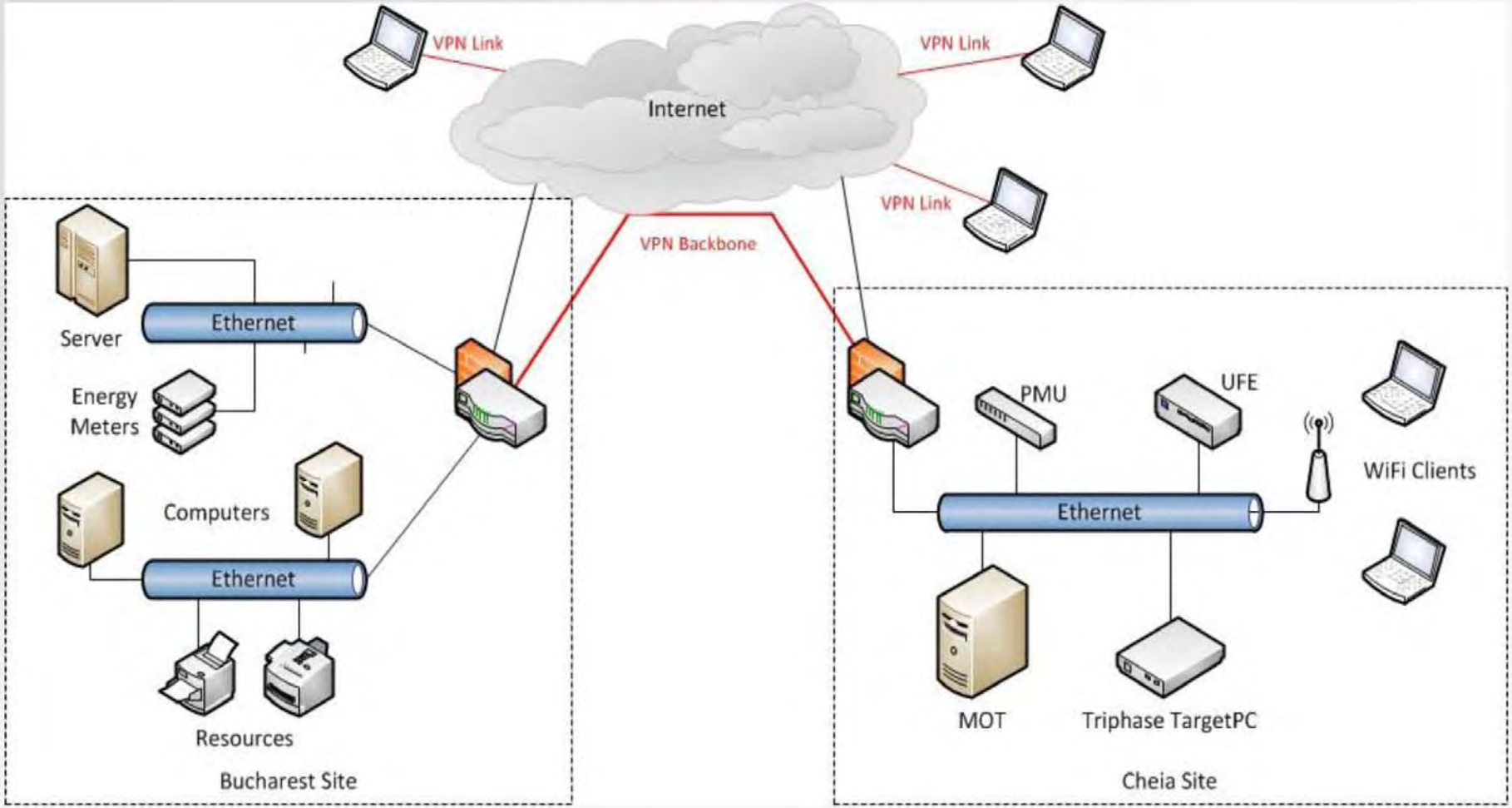
Communication and Measurement

- 2 independent devices
- Autonomy in data management
- Permanent connection to the Internet

Monitoring Equipment

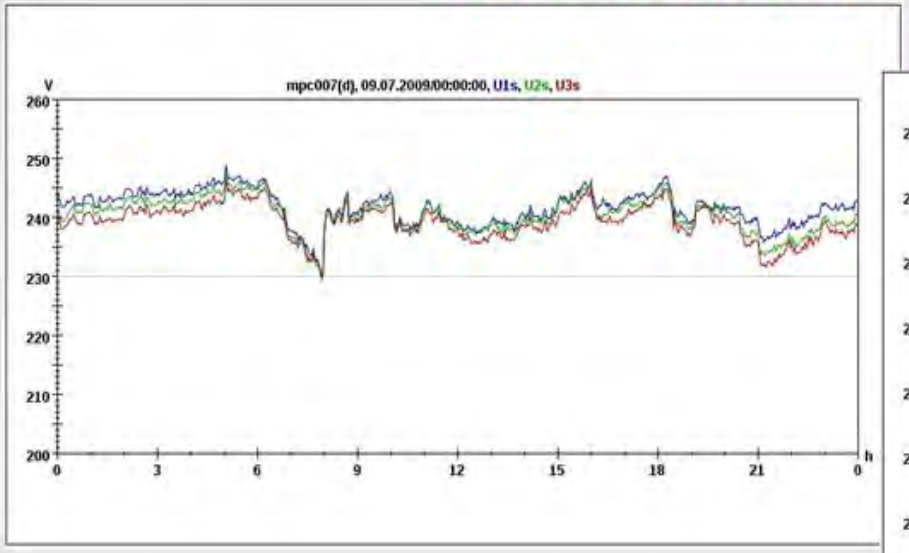
- MOT Device:
  - RS232 Interface for the communication with the PC
  - Autonomous software for data and disk space management
  - FTP enabled for data download
- Ufe Device:
  - Ethernet interface for communication
  - Data exchange with the storage server through VPN
  - Remote administration through Web GUI
- PMU (Arbiter Systems) – since 21st of May 2010

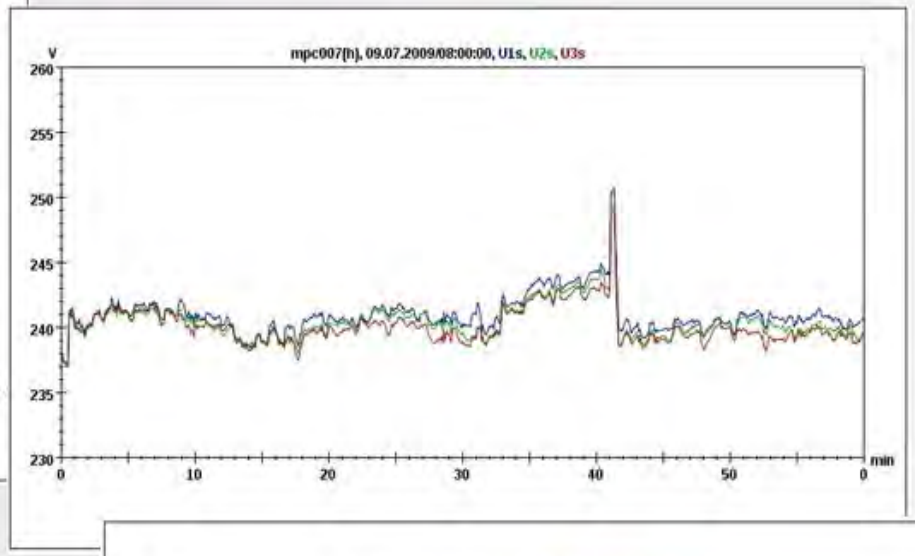
Communication and Measurement

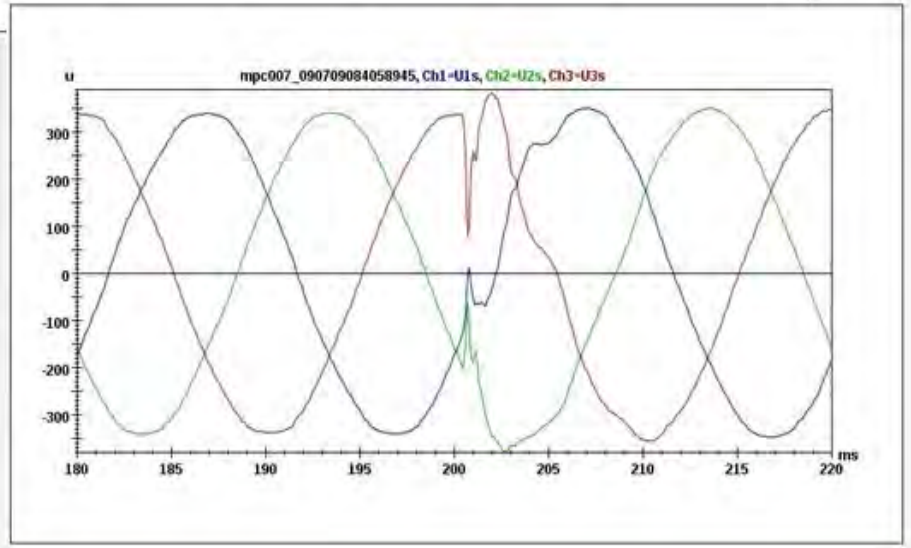


Network monitoring and control (2010)

Communication and Measurement







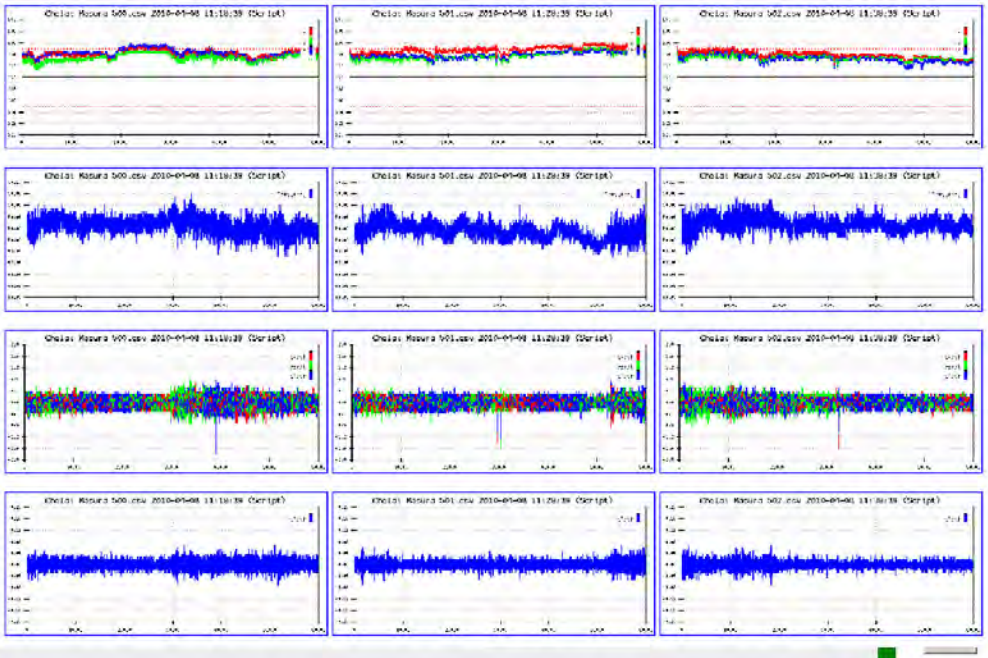
Voltages as recorded in Cheia on 09.07.2009 using the UfE equipment

a) rms values of a day;

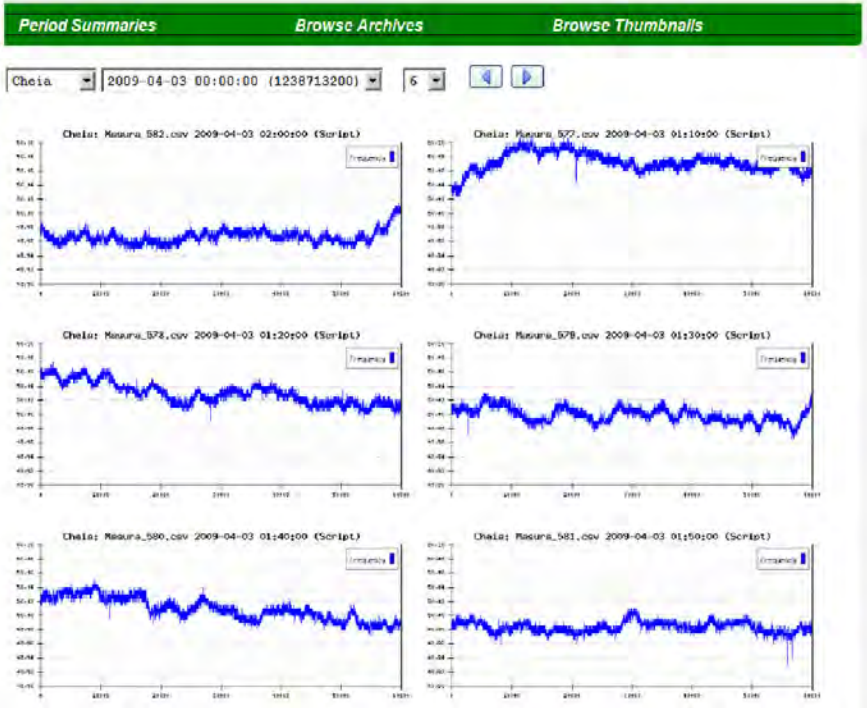
b) rms values of an hour;

c) waveform

Communication and Measurement

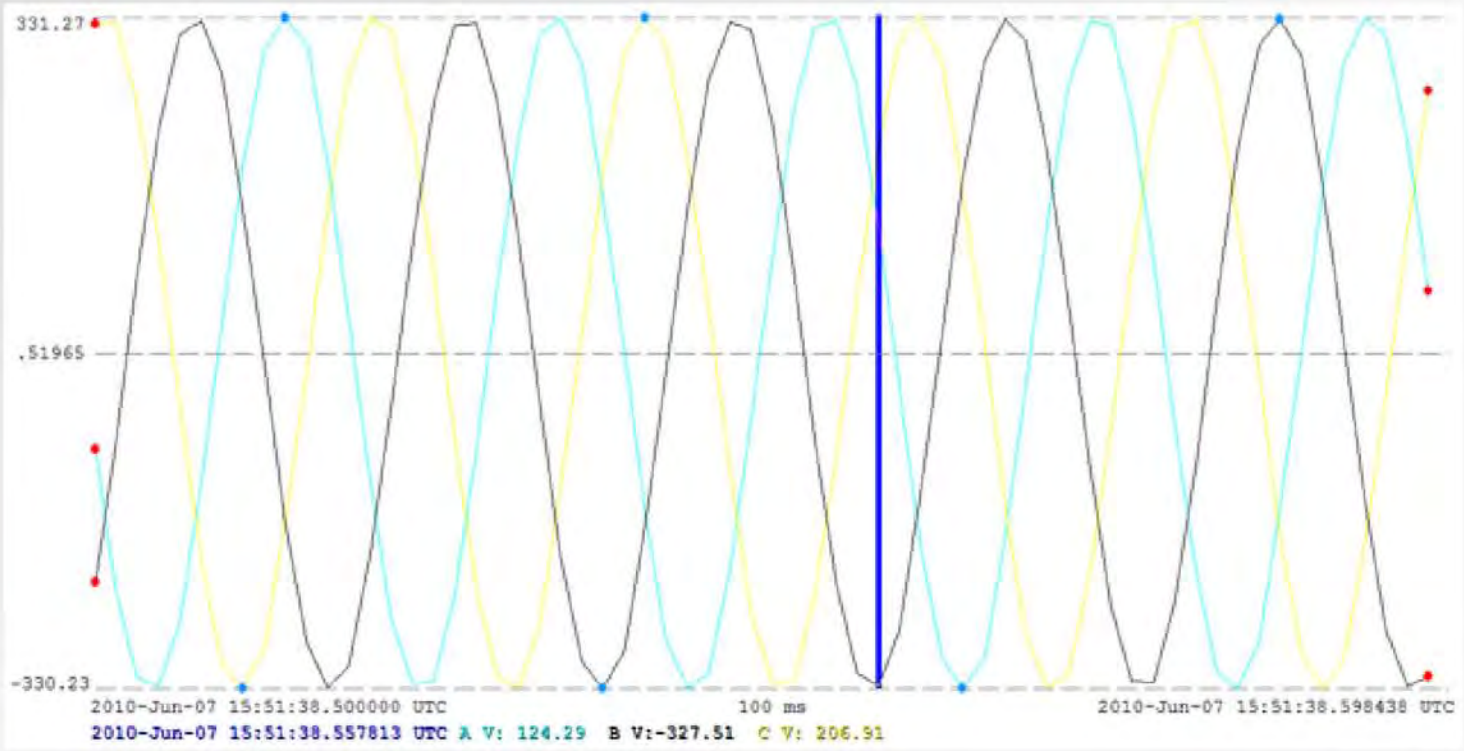


Voltage and frequency derivatives signals for 30 minutes recording– 8 april 2010



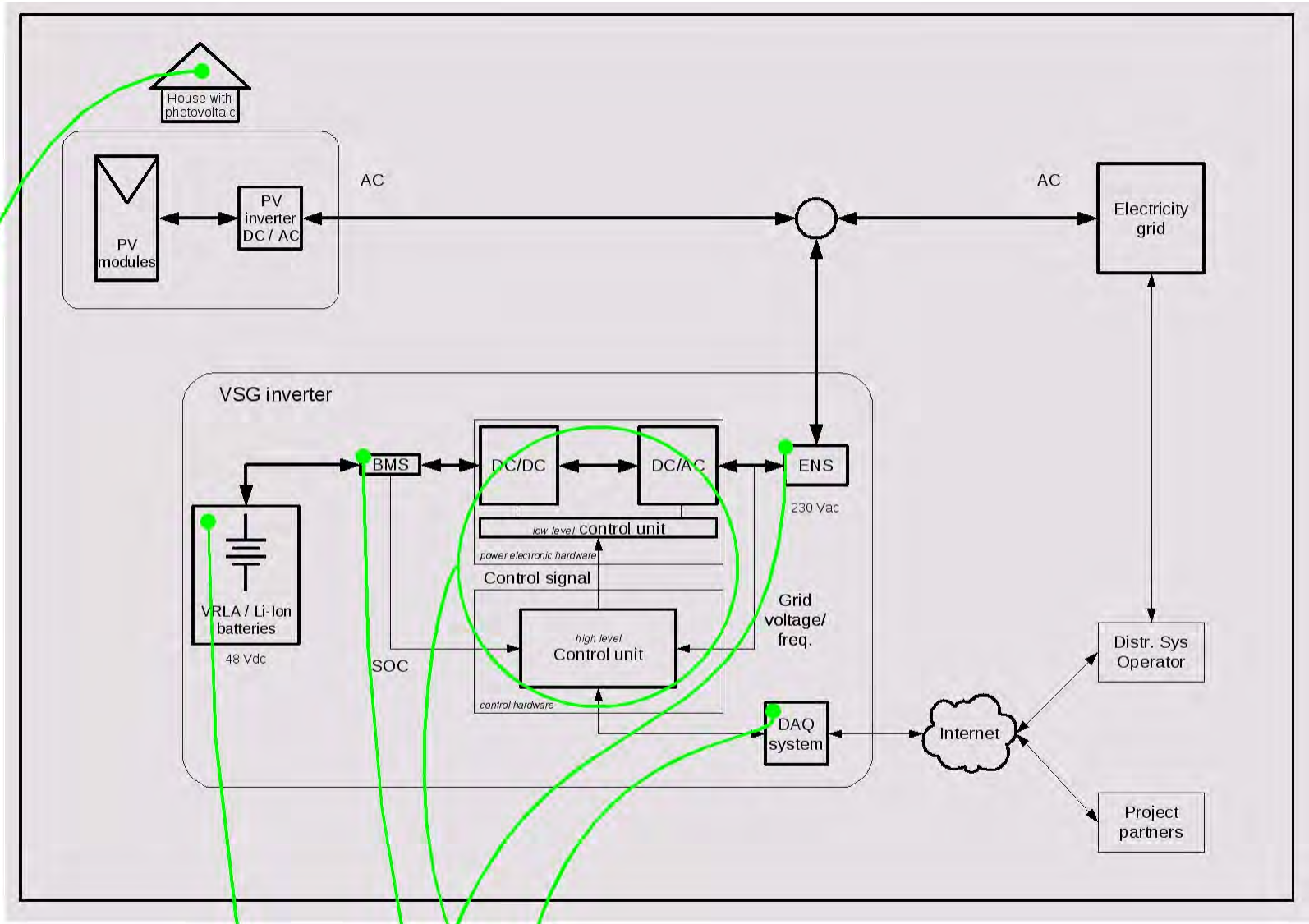
frequency variation for 60 minutes registration in April 2009, with a 10ms time resolution.

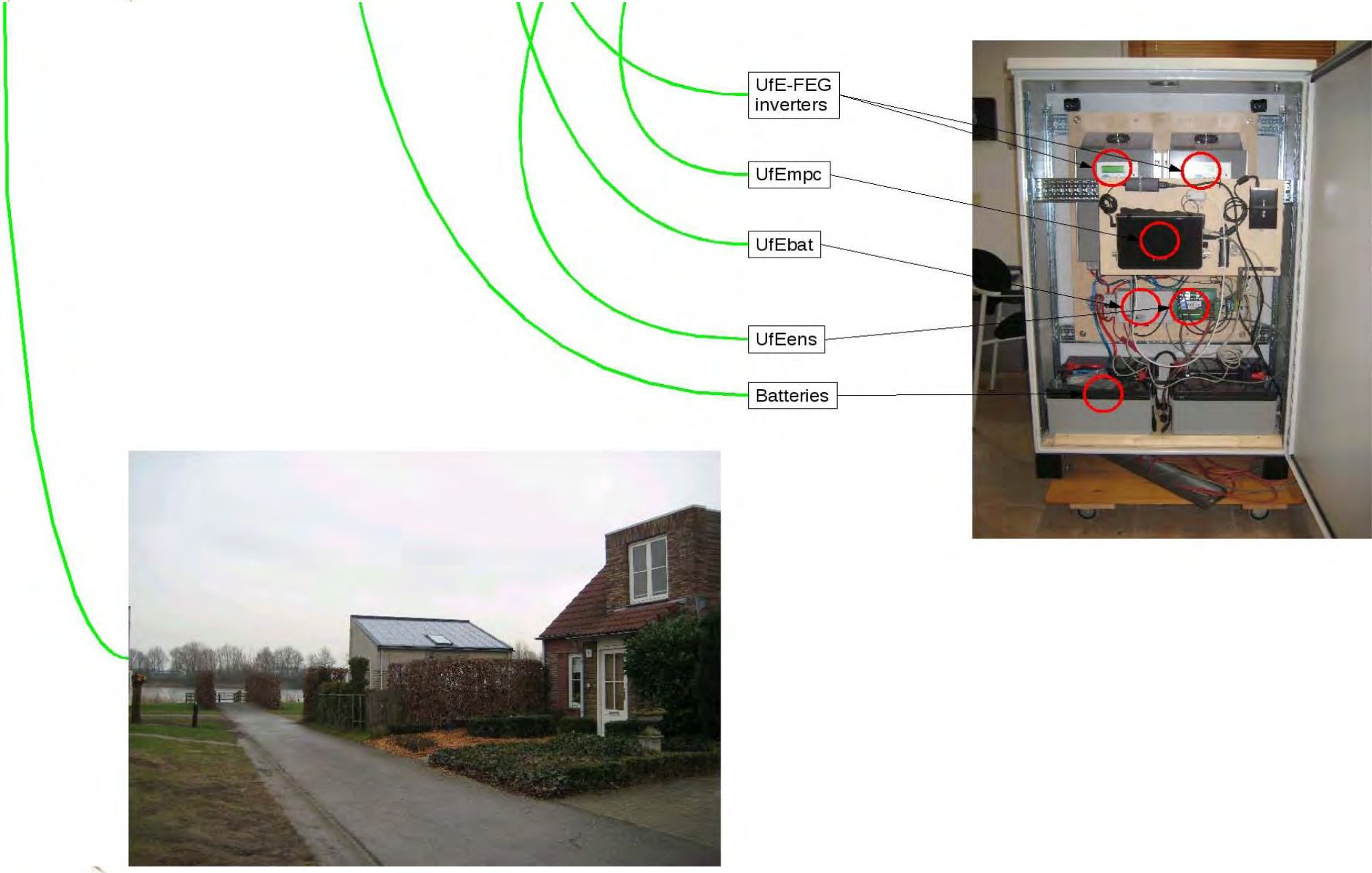
Waveforms captured with the Phasor Measurement Unit at Cheia, Romania.



Index

- Who are we?
- Why smartgrids?
- Actual situation
- Proinver project
- VSYNC project
  - Vsg requirements
  - Tecnalia proposed control system.
    - Tests and results
  - Vsync project demo sites
    - Cheia (Romania)
    - Bronsbergen (Nederland)


House with photovoltaic
PV modules
PV inverter DC / AC
AC
AC
Electricity grid
VSG inverter
BMS
DC/DC
DC/AC
ENS
230 Vac
low level control unit
power electronic hardware
Control signal
high level
Control unit
control hardware
VRLA / Li-Ion batteries
48 Vdc
SOC
Grid voltage/ freq.
DAQ system
Internet
Distr. Sys Operator
Project partners


UfE-FEG inverters
UfEmpc
UfEbat
UfEens
Batteries

Thanks for your Attention

Asier Gil de Muro

LABEIN-Tecnalia

Active Distribution Researcher

Parque Tecnológico de Bizkaia – Edif. 700

48160 – Derio (Bizkaia)

Email: asier@labein.es

Tel: +34 94 607 33 00