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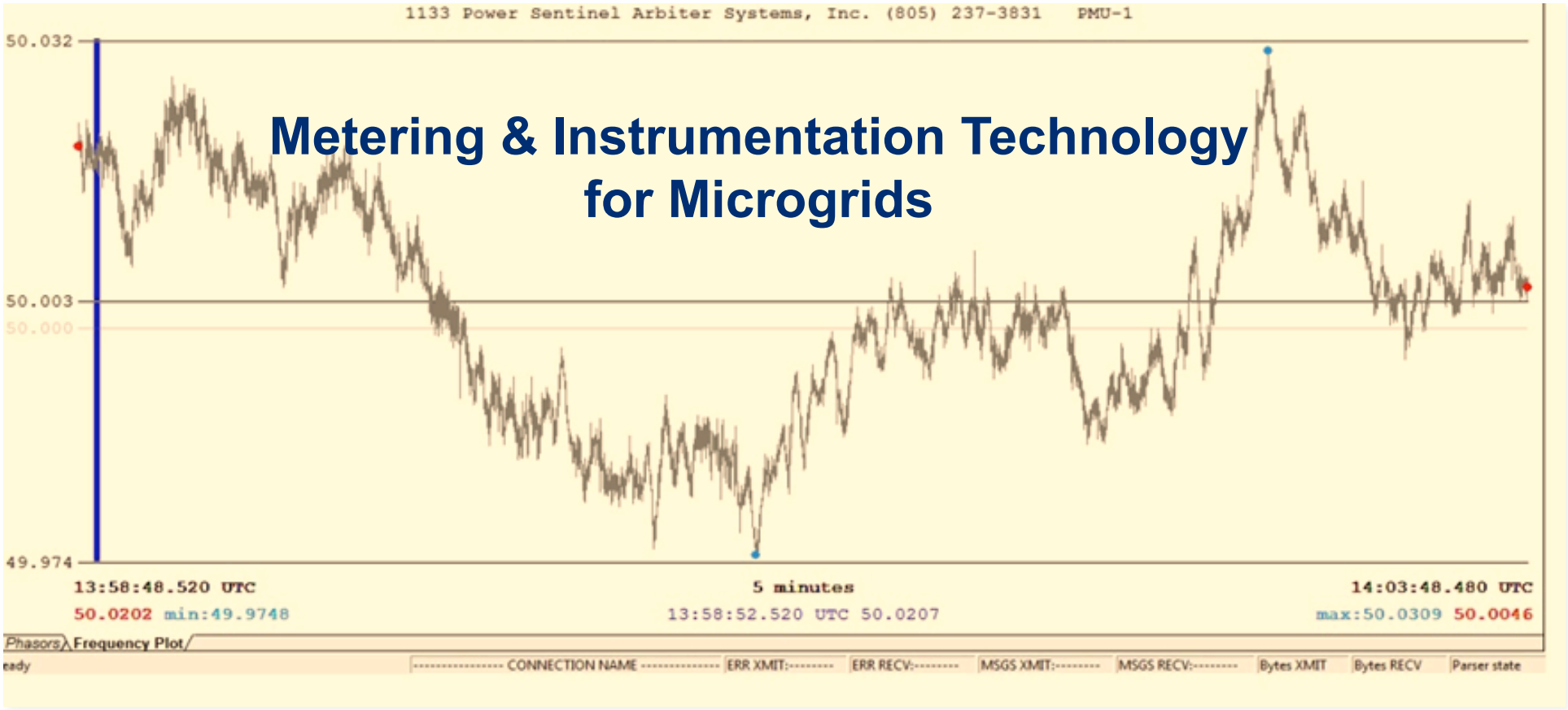

Metering & Instrumentation Technology for Microgrids

Mihaela Albu

Politehnica University of Bucharest

Évora 2012 Symposium on Microgrids, 3 Sept. 2012

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Outline

- metering
  - smart metering
  - smart services & the European smart metering landscape report
  - smart meters functionalities
  - integration of information from different networks (and energy vectors)
- monitoring processes in microgrids
  - new processes /new paradigm / new models
- instrumentation and measurement
  - measurement uncertainties and data processing
  - state estimation and grid models
- matching the measurement chain to the application
  - dc microgrid
  - virtual synchronous generator

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Metering

- Smart Grid[s] agenda includes several topics in view of attaining sustainability
  - the EU2020 Agenda
  - "Without **serious upgrading of existing grids** and **metering**, renewable energy generation will be put on hold, security of the networks will be compromised, opportunities for energy saving and energy efficiency will be missed, and the internal energy market will develop at a much slower pace"
  - Smart Grids: "an upgraded electricity network to which two-way digital communication between supplier and consumer**, intelligent metering** and **monitoring systems** have been added. **Intelligent metering** is usually an inherent part of Smart Grids".

[COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS
Smart Grids: from innovation to deployment , 14 April 2011]

- **Smart metering** stands out as a truly transformative new technology to improve **energy metering and billing system**s and to enable better awareness for energy end-users. However, smart meters themselves are **only enabling technologies**, which need to be coupled with innovative services.
- **Instrumentation** is required by smart metering, and it is also **mandatory** for all processes involved by smart grids.

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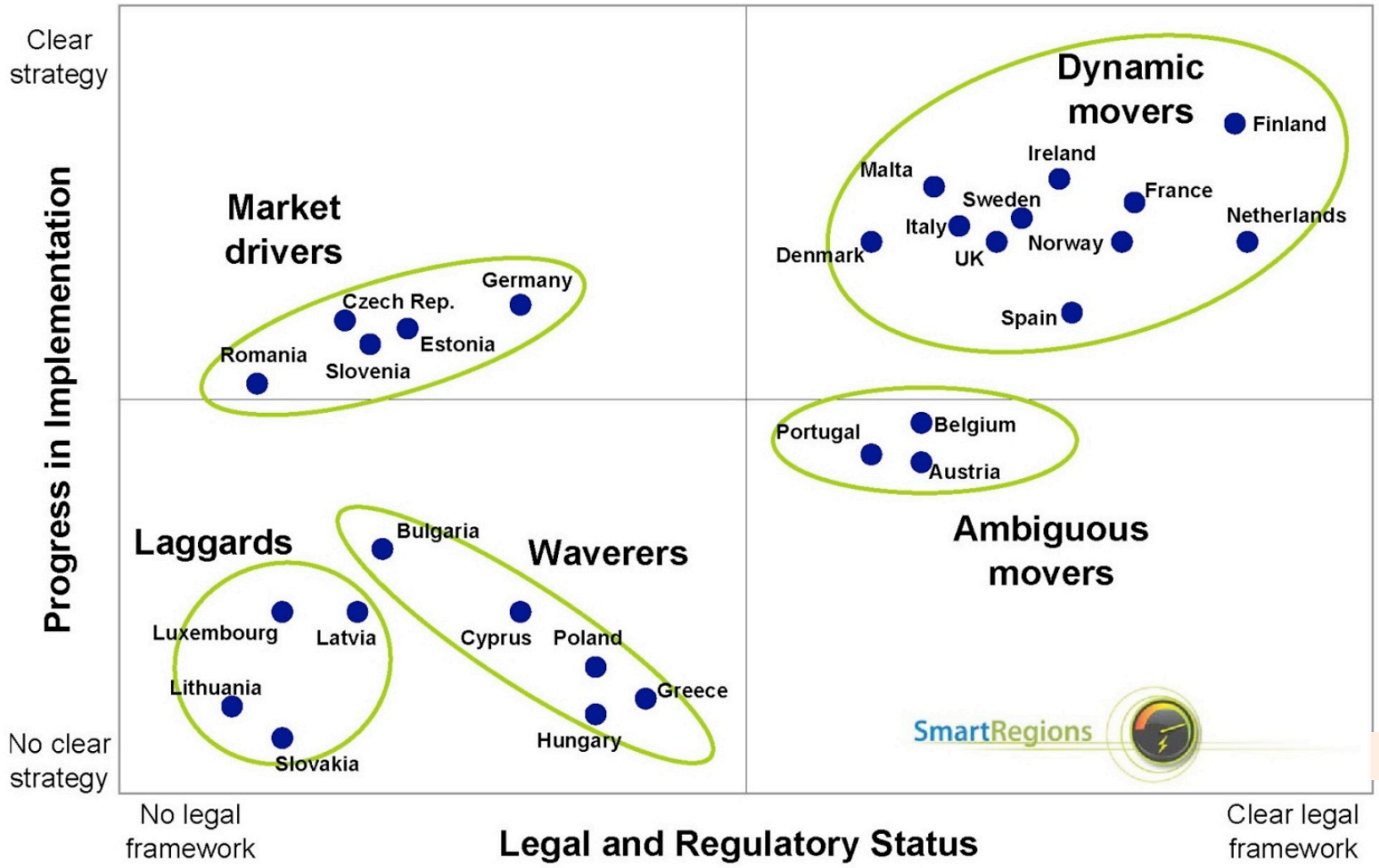
European Smart Metering Landscape



Febr. 2011

IEE-SmartRegions project - www.smartregions.net

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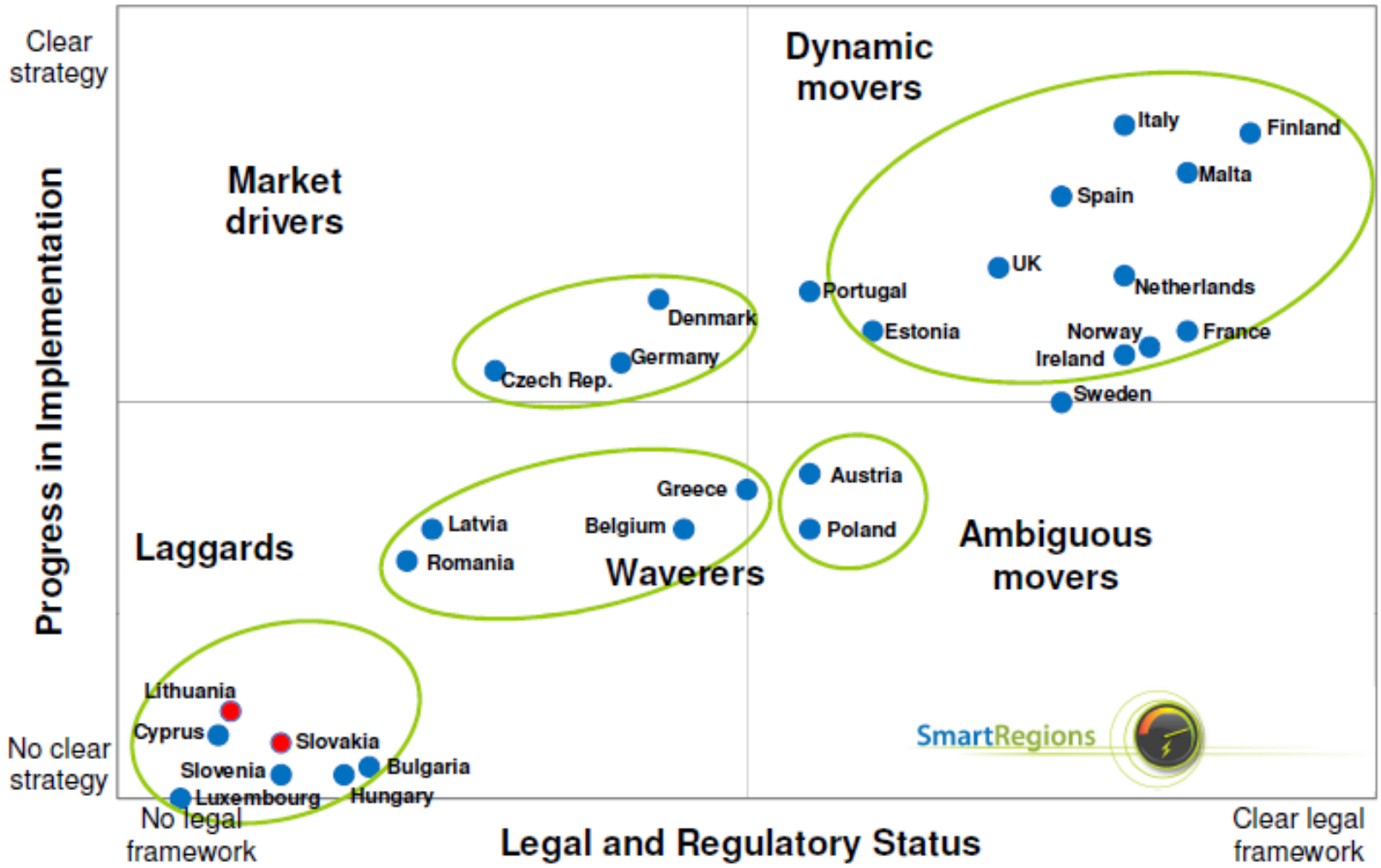
European Smart Metering Landscape



June 2012

IEE-SmartRegions project - www.smartregions.net

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Smart Metering functionalities

- In 2011 based on the 11 CBAs performed by European countries (Austria, Belgium, France, Ireland, Netherlands, Norway, Poland, Portugal, Slovenia, Sweden and UK) the EU Commission defined a Smart Metering System in terms of **13 key Functionalities:**

  - **For the Customer (1-3)**
  - **For grid & network support (4-7)**
  - **For commercial aspects of energy supply (8-10)**
  - **For security and privacy (11-12)**
  - **To allow distributed generation (13)**

A joint contribution of DG ENER and DG INFSO towards the Digital Agenda, Action 73: Set of common functional requirements of the SMART METER (http://ec.europa.eu/information_society/activities /sustainable_growth /docs/smart-meters smart_meter_funtionalities_report.pdf)

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Smart Metering functionalities

1. Provides **readings** from the meter to the customer and to equipment that he may have installed;
2. **Updates these readings** frequently enough to allow the information to be used to achieve energy savings;
3. Provides these **readings in a form** easily understood by the untrained consumer, and with calculations enabling final customers to better control their energy consumption
4. Allows **remote reading of meter registers** by energy suppliers and by grid operators;
5. Provides two-way communication between the meter and external networks (both supply & grid) for maintenance and control of the meter;
6. Provides for the **monitoring of Power Quality**;

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Smart Metering functionalities

7. Allows readings to be taken frequently enough to allow the information to be used for **grid control**.
8. Supports advanced tariff systems. Includes multiple tariffs, time of use registers, block tariff registers, remote tariff control, etc as applicable;
9. Supports energy supply by pre-payment and on credit
10. Allows **remote ON/OFF control** of the supply and/or flow or power limitation.
11. Provides Secure Data Communications;
12. Fraud prevention and detection.
13. Provides Import / Export & Reactive Metering.

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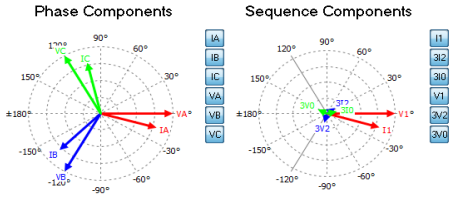
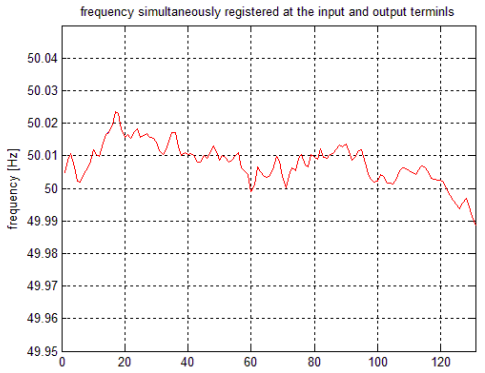
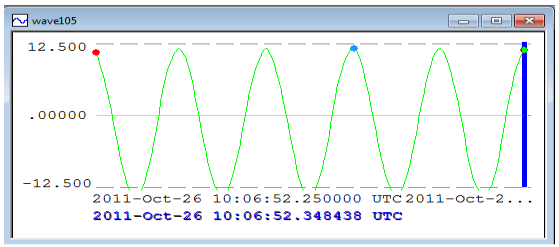
Monitoring processes in microgrids



- New processes. Holistic approach. Multiple energy vectors
  - new instruments (synchronized measurements);
  - different time constants: redefinition of “real-time”
  - instantaneous values for measured quantities vs. [successive] averaging
- New paradigm
  - active distribution grids; microgrids, dc grids,
  - storage, electric vehicles;
  - generation intermittency;
  - load profiles with limited knowledge
  - low inertia
- New models.
  - metering
  - instrumentation
  - measurements
  - **data**





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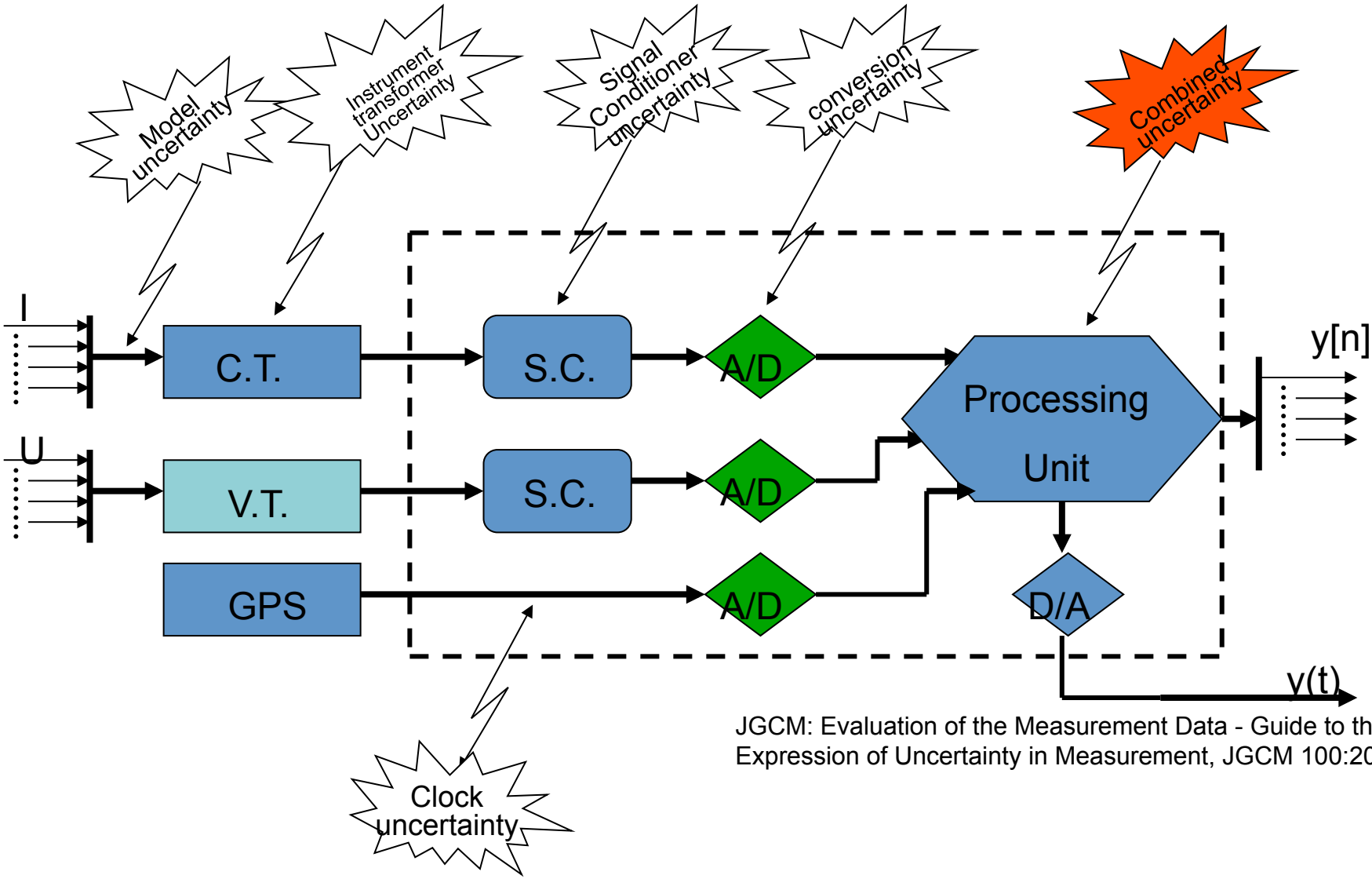
Instrumentation and measurement



JGCM: Evaluation of the Measurement Data - Guide to the Expression of Uncertainty in Measurement, JGCM 100:2008.

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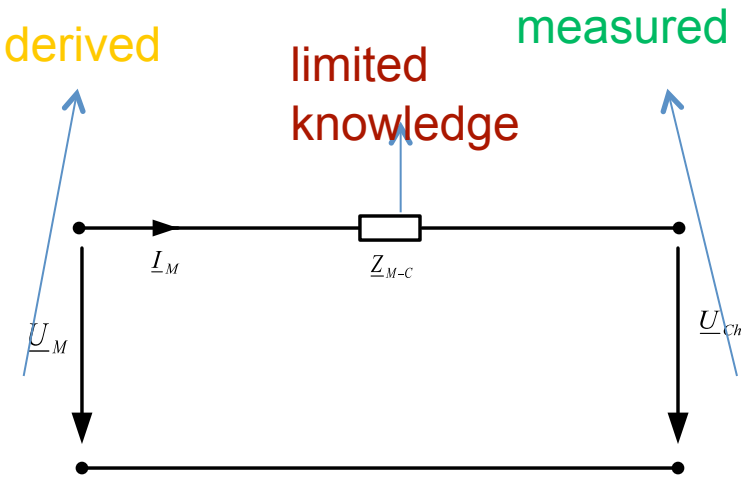
Measurement uncertainties and the network elements model

- assumed availability of phasor measurements
- concentrated parameters model (positive sequence quantities).
- a method to derive the network parameter model



$$U_M = f_{uM}\left(U_{Ch}, \alpha_{Ch}, I_M, \varphi_M, r_0, l_0, f, L_{M-C}\right)$$

$$\frac{\partial f_{u_M}}{\partial L_{M-C}} = \frac{L_{M-C} r_0^{\,2} I_M^{\,2} + L_{M-C}\left(2\pi f_0 l\right)^2 I_M^{\,2} + U_{Ch} r_0 I_M \cos\left(\varphi_M - \alpha_{Ch}\right)}{\left|U_M\right|} -$$

$$- \frac{2L_{M-C}\left(2\pi f_0 l r_0\right) I_M^{\,2} \sin\left(2\varphi_M\right) + 2\pi f_0 l U_{Ch} I_M \sin\left(\varphi_M + \alpha_{Ch}\right)}{\left|U_M\right|}$$

M. Albu, E. Kyriakides, A. Dumitrescu, and I. M. Florea, "Analysis of distribution grids: state estimation using model uncertainties," *2nd IEEE International Workshop on Applied Measurements for Power Systems (AMPS 2011)*, Aachen, Germany, pp. 1-4, Sep. 2011

$$u_{U_M} = \sqrt{\sum_{j=1}^{8}\left(\frac{\partial f_{uM}}{\partial M_j}\right)^2 \left(u_{M_j}\right)^2}$$

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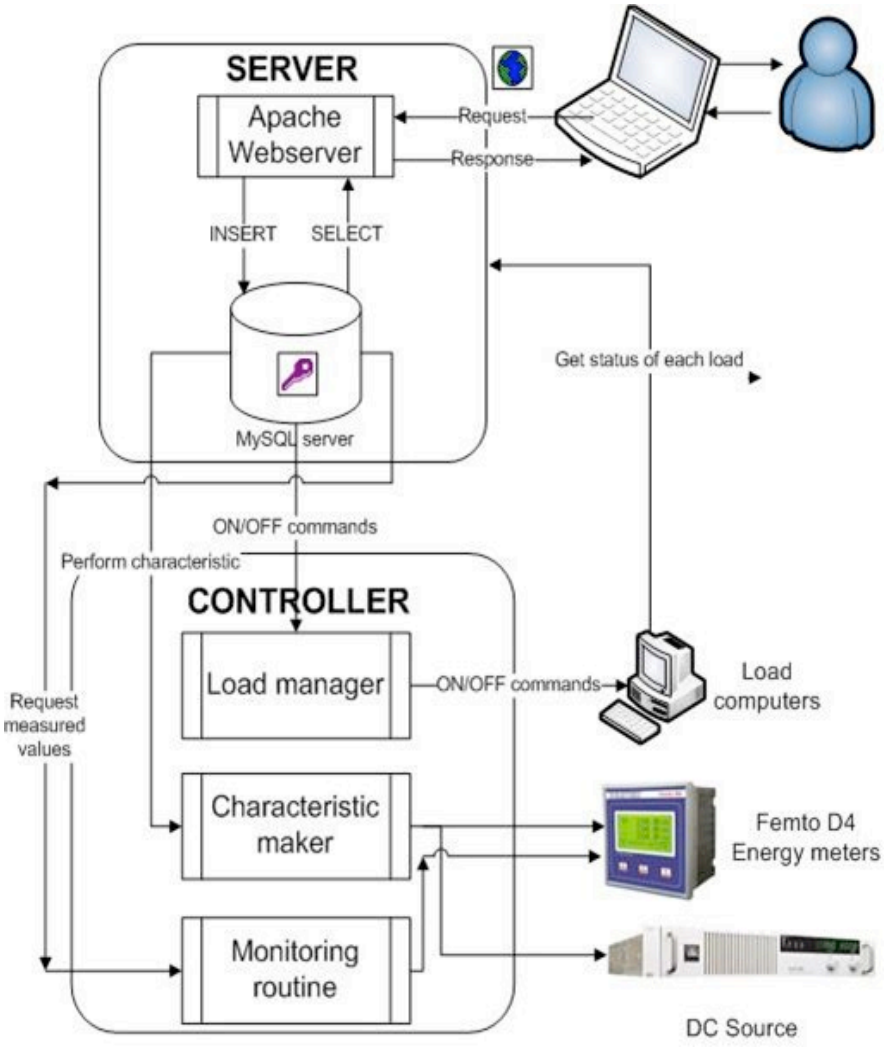
Matching the measurement chain to the application.

A DC laboratory microgrid @ UPB



Full integration of measurement modules into unique system; flexibility; automation; ease of access; security.

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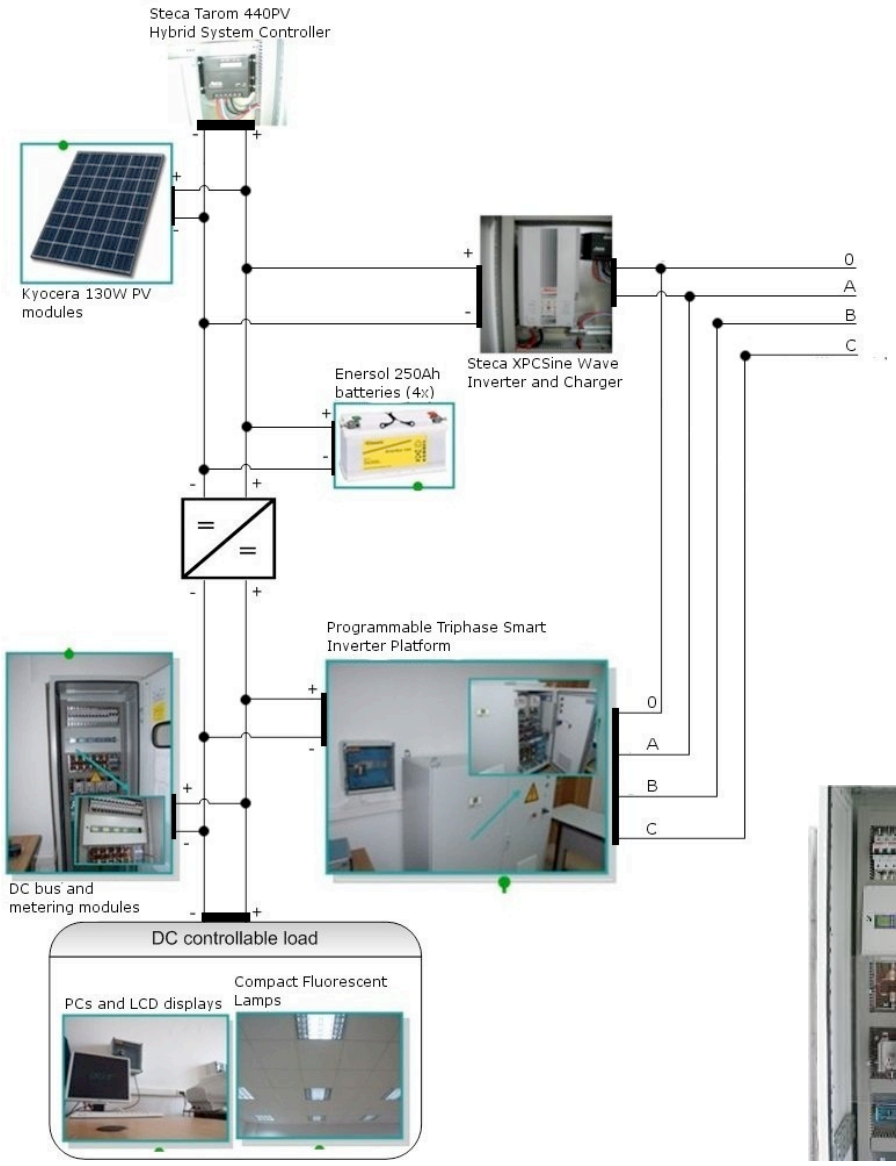
Matching the measurement chain to the application.

A DC laboratory microgrid @ UPB



Electrex energy meters

5 dedicated Energy Meters - FEMTO D4 RS485 230-240V

YOCTONET D4 Ethernet Bridge - conversions between RS485 interface and Ethernet

Returned data is stored in input registers using the Float IEEE754 format

Reading data from the registers is done by using ModBus TCP protocol

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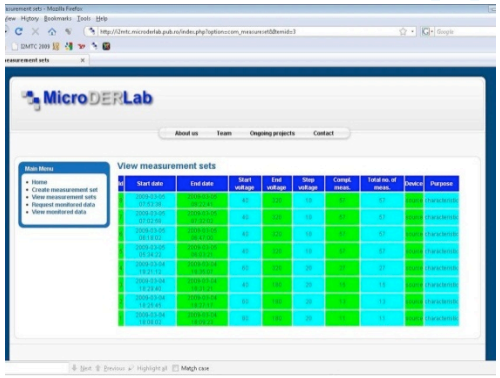
Matching the measurement chain to the application.

A DC laboratory microgrid @ UPB – Communication layer

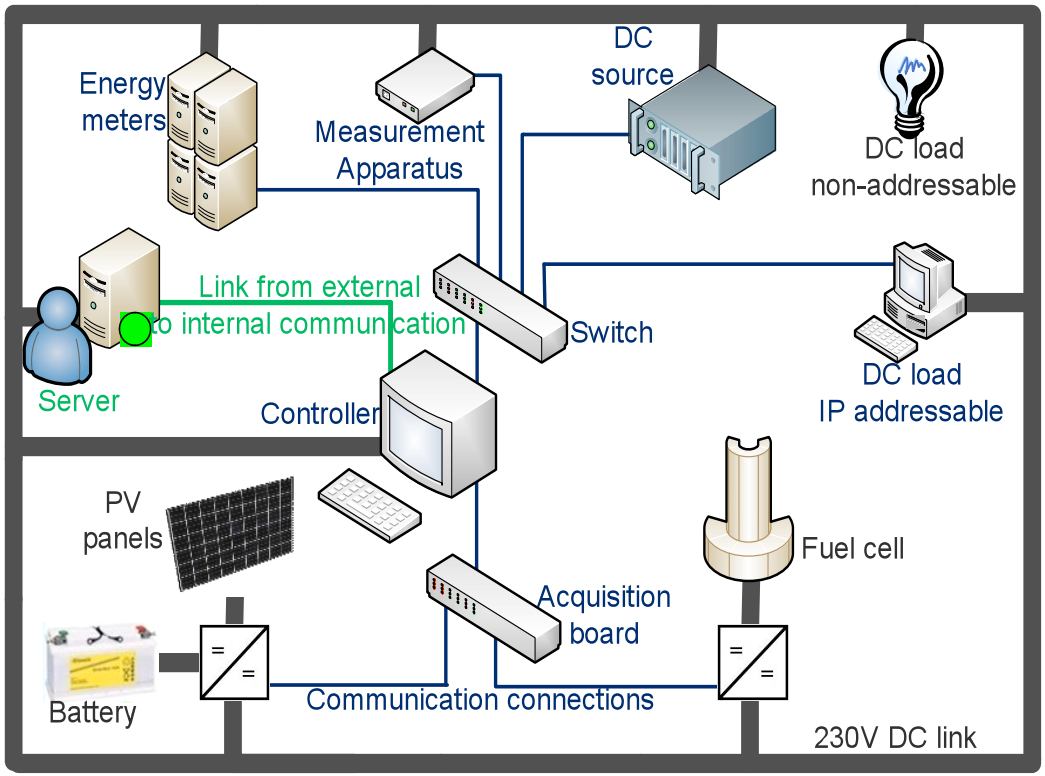


Online control the DC grid achieved with minimal requirements from the client side

Database mediated data transfer among modules ensures a collision free and reliable communication

Measurement database of the DC characteristics - a valuable resource for further research on the applications of DC microgrids in the end-user sector

Developing algorithms for minimizing the amount of power taken form the grid



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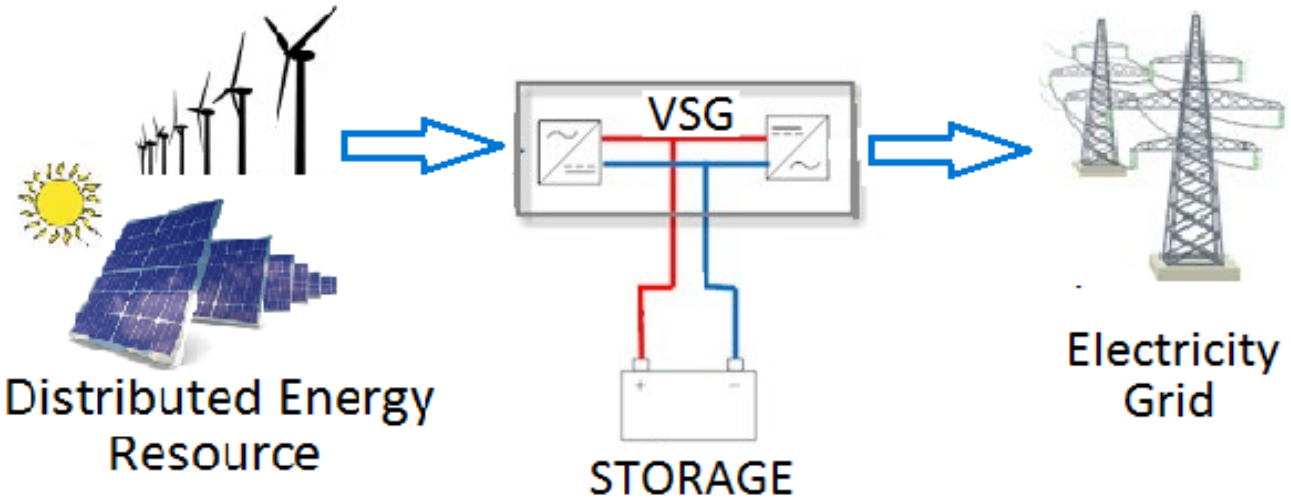
Matching the measurement chain to the application.

A VSG field test demonstration - @ Cheia, Romania

- One year measurement campaign in 4 locations.
- Each location, each ten minutes interval: 60.000 recordings (rms voltage values and frequency aggregated data – IEC 61000-4-30)
- Cheia: demonstration of the VSG concept
  - accurate on-line data for algorithms testing.
  - isolated area
  - solution: a stub zone connected through a secured VPN tunnel over a WCDMA mobile connection to the server



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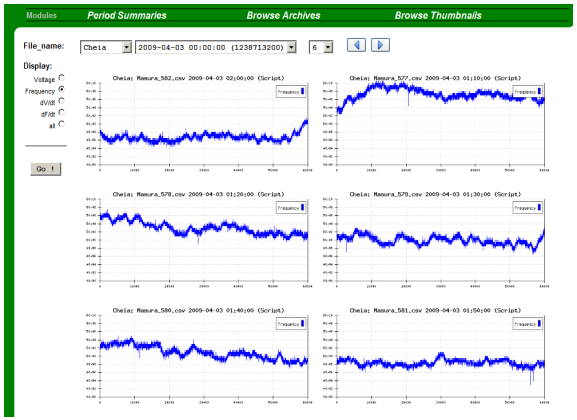
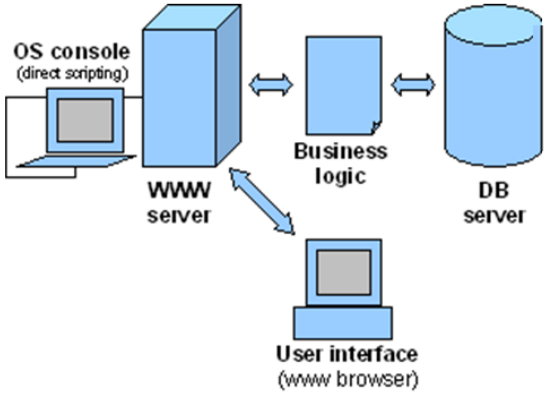
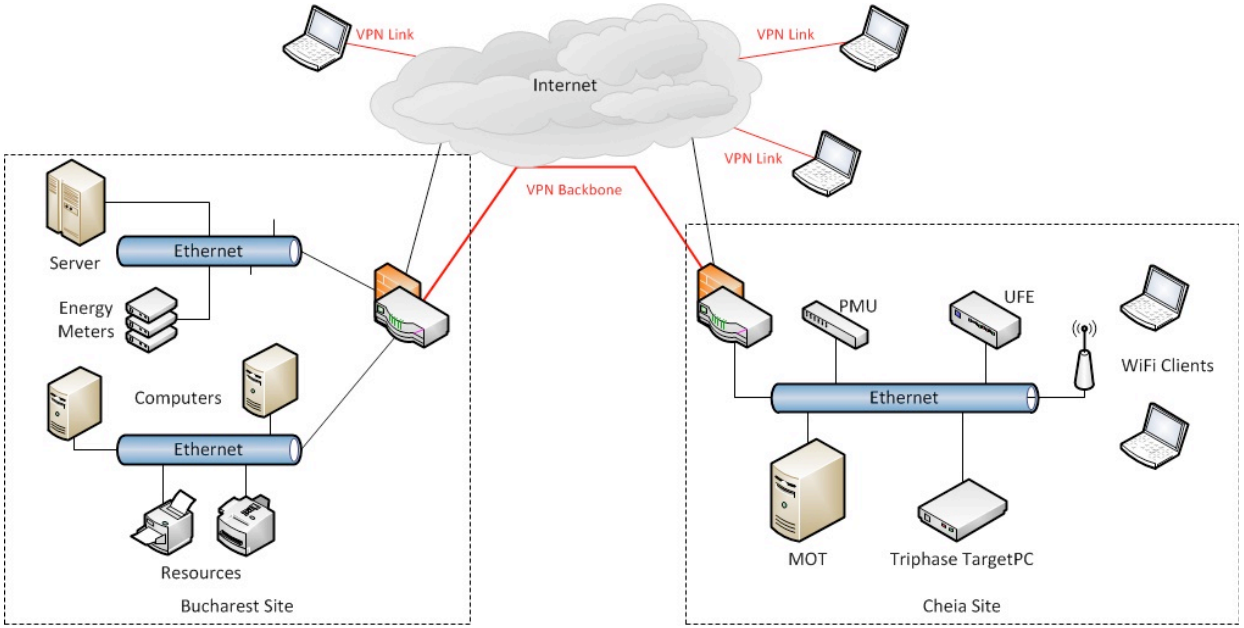
Matching the measurement chain to the application.

A VSG field test demonstration - @ Cheia, Romania

Voltage and frequency monitoring







↳ frequency and voltage variations at PCC): an extensive monitoring campaign initiated in 2008.

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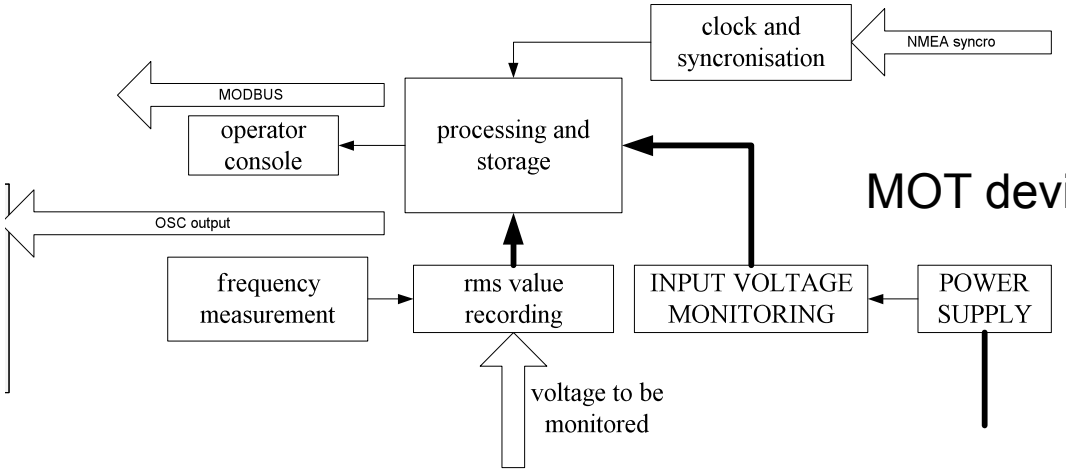
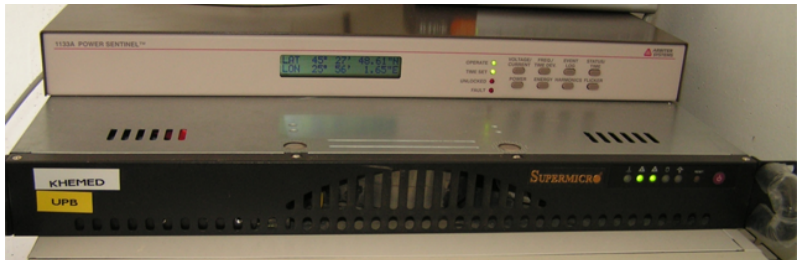
Matching the measurement chain to the application.

A VSG field test demonstration - @ Cheia, Romania
Voltage and frequency monitoring

UfE device: pseudo-PMU, a low-cost computer connected with a versatile DAQ card (and corresponding sensing elements), including a GPS module→ a 4-channels PMU, 16 bits/44.1 kHz



MOT device (half cycle rms values)



Arbiter 1133 Power Sentinel PMU

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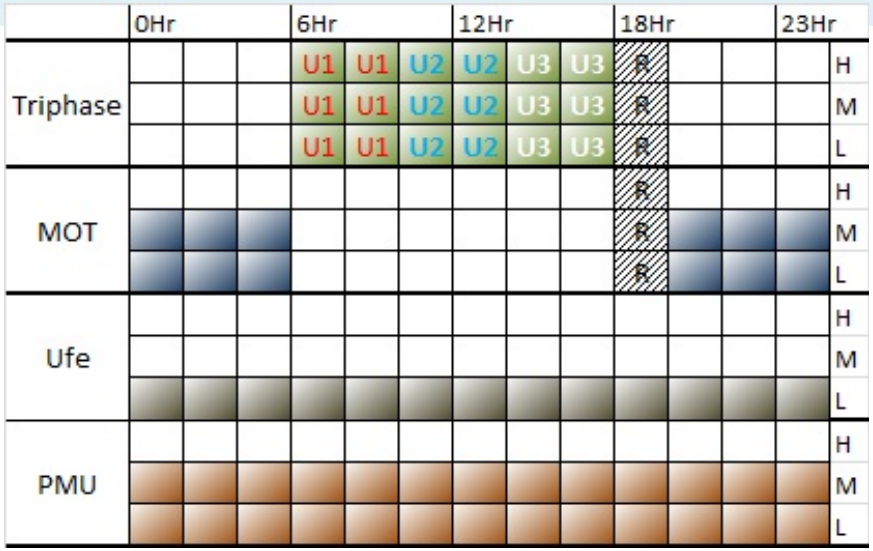
Matching the measurement chain to the application.

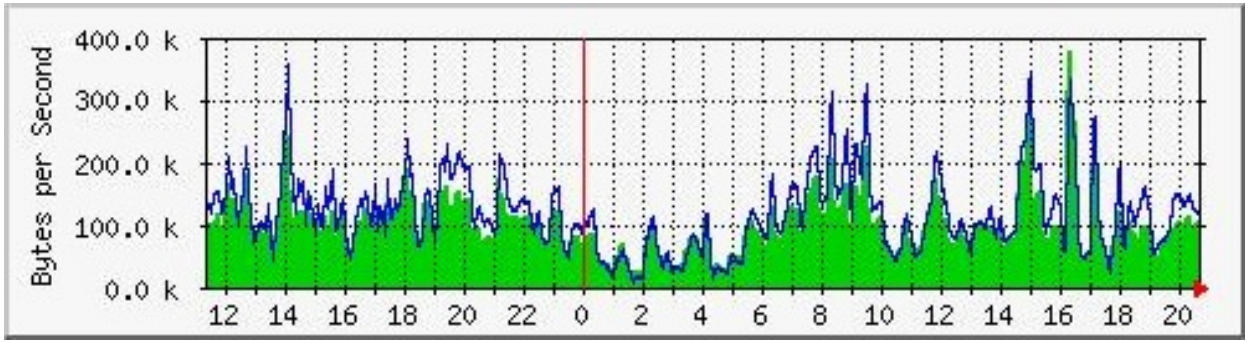
A VSG field test demonstration - @ Cheia, Romania
Voltage and frequency monitoring – Communication



Bandwidth Allocation

U#= SG application Remote Test User #
R = Reserve for critical transfers
L = Low Bandwidth Need
M = Medium Bandwidth need
H = High Bandwidth Need

Daily Internet link usage for VSG project in Cheia (including voltage and frequency monitoring)



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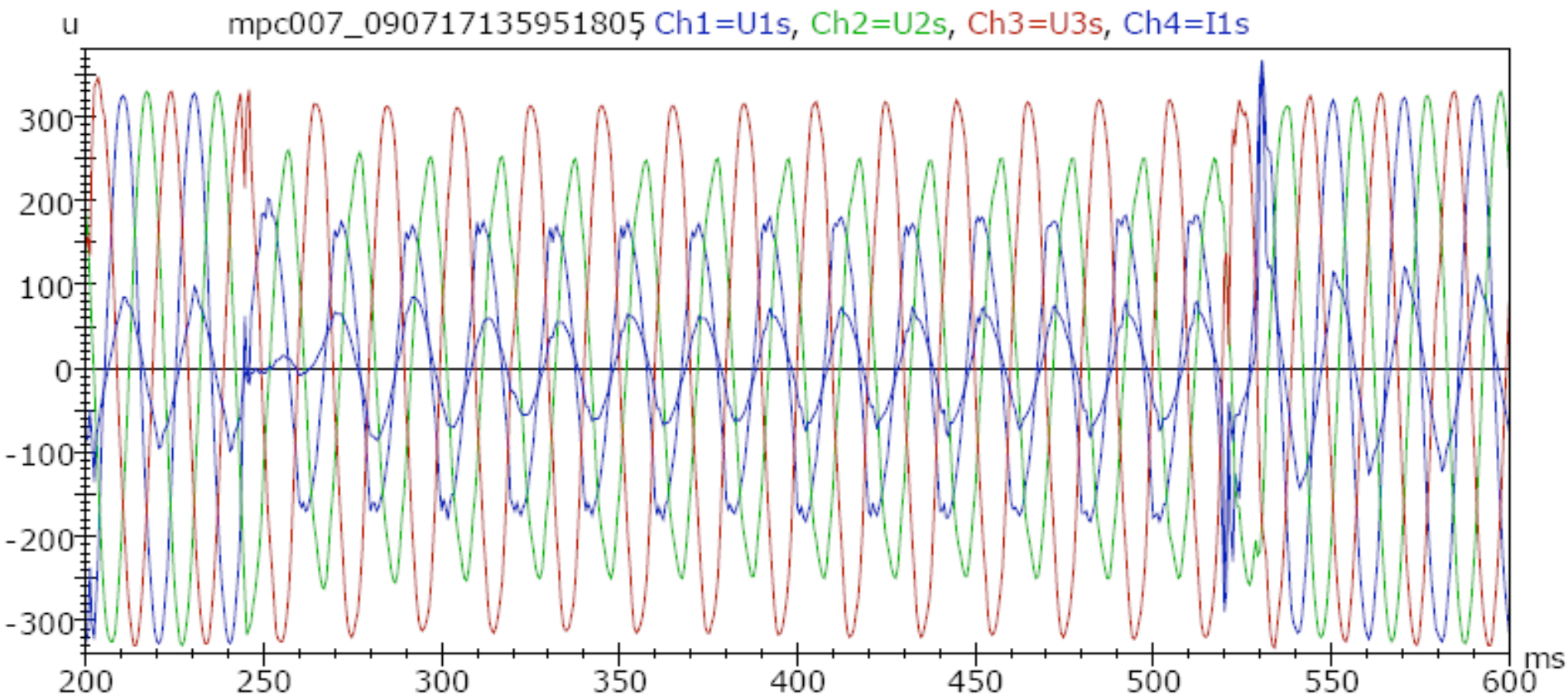
Matching the measurement chain to the application.

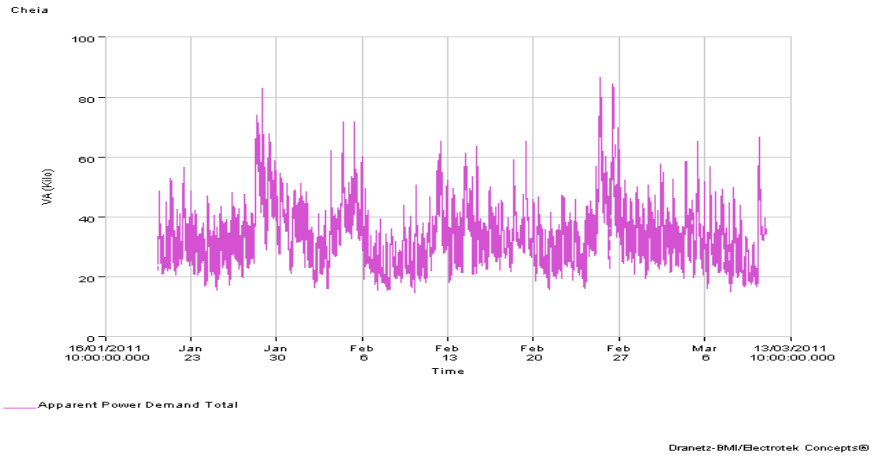
A VSG field test demonstration - @ Cheia, Romania
waveforms recording

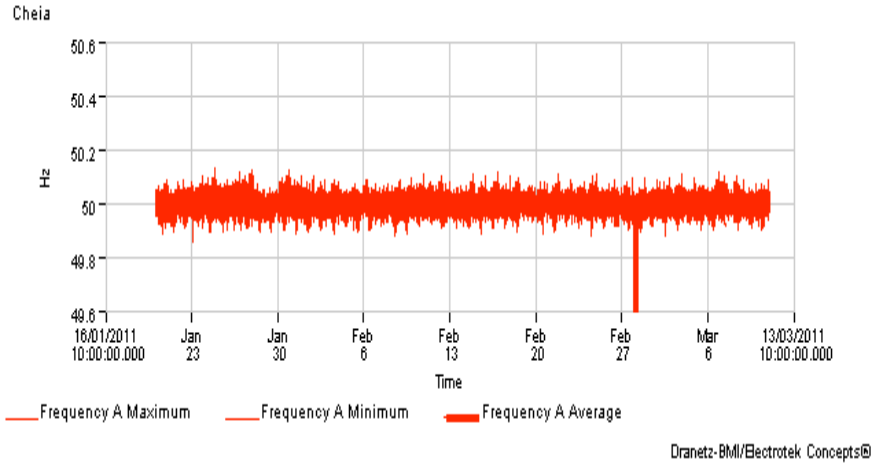


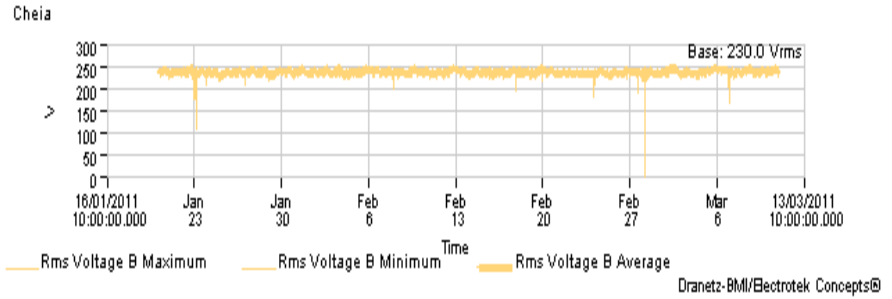
Matching the measurement chain to the application.

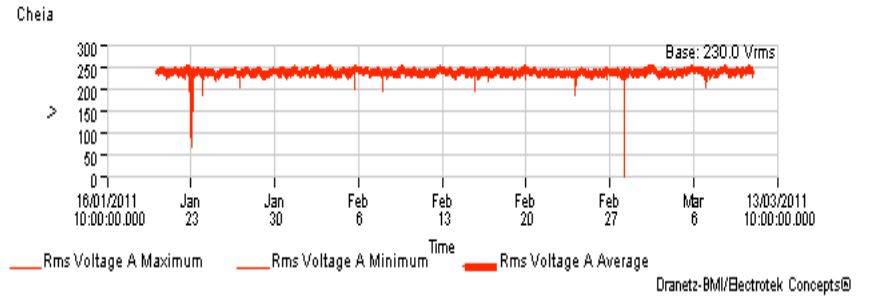
A VSG field test demonstration - @ Cheia, Romania

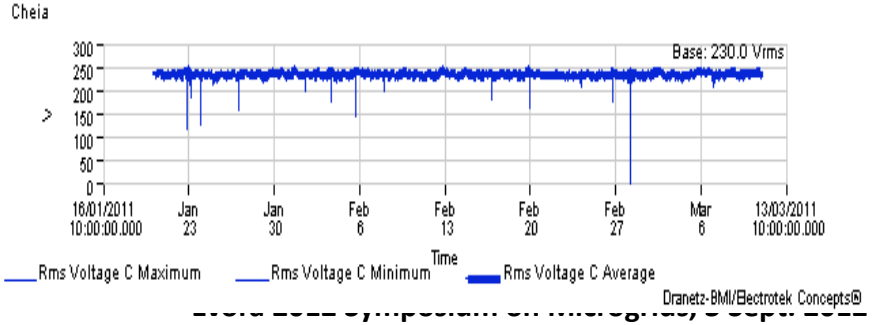
Measurements from site











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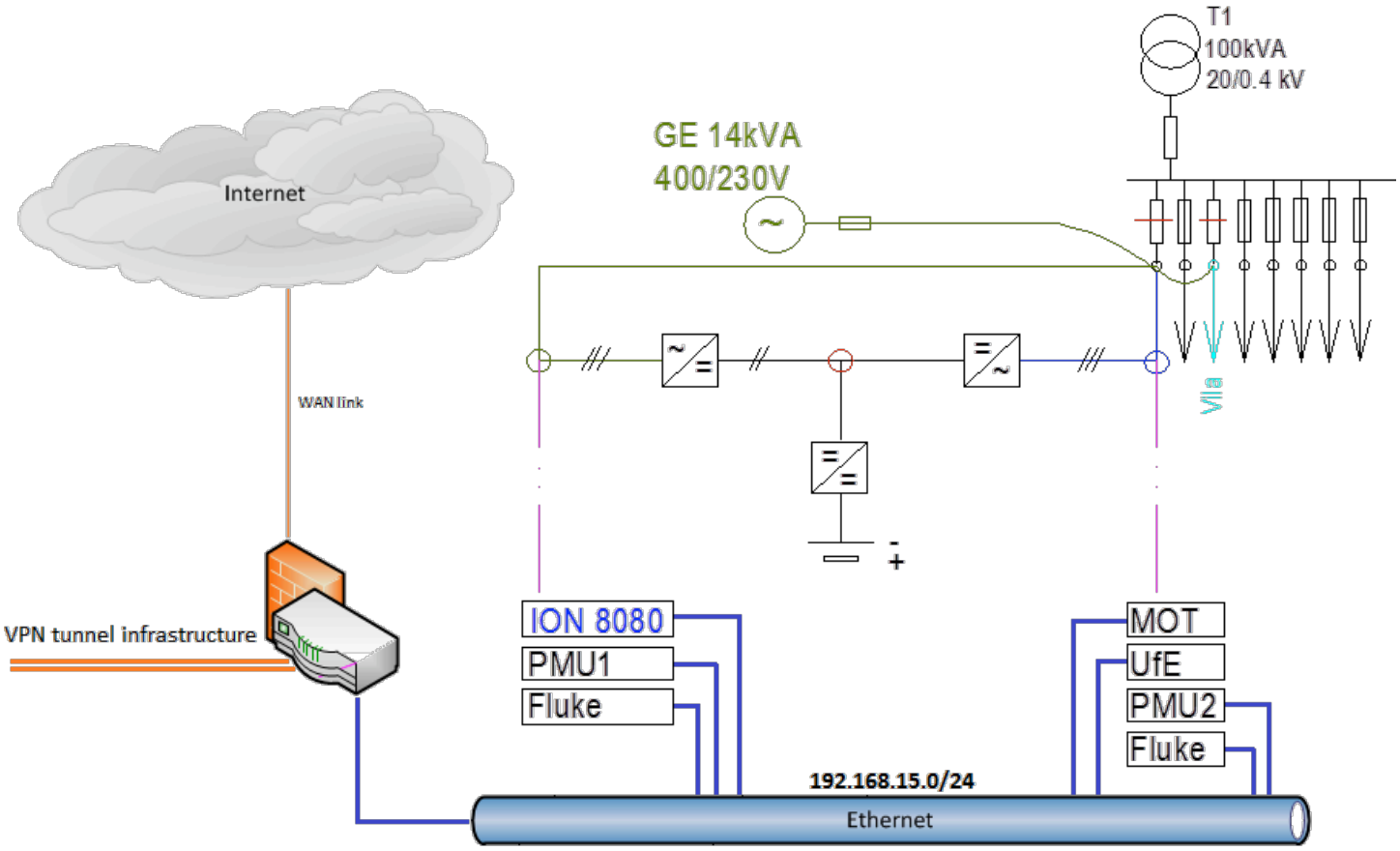
Matching the measurement chain to the application.

A VSG field test demonstration - @ Cheia, Romania
Data Communication

Most of the tests have been performed remotely from Bucharest site by connecting to the equipment in Cheia through the VPN infrastructure.

During the tests 2 PMU devices were deployed in Cheia, each one acquiring data from different points in the grid.



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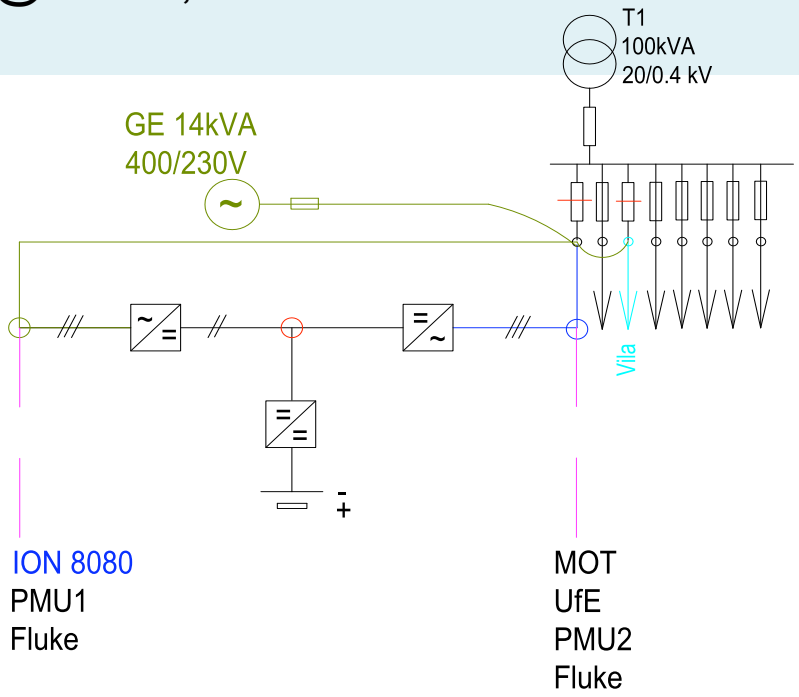
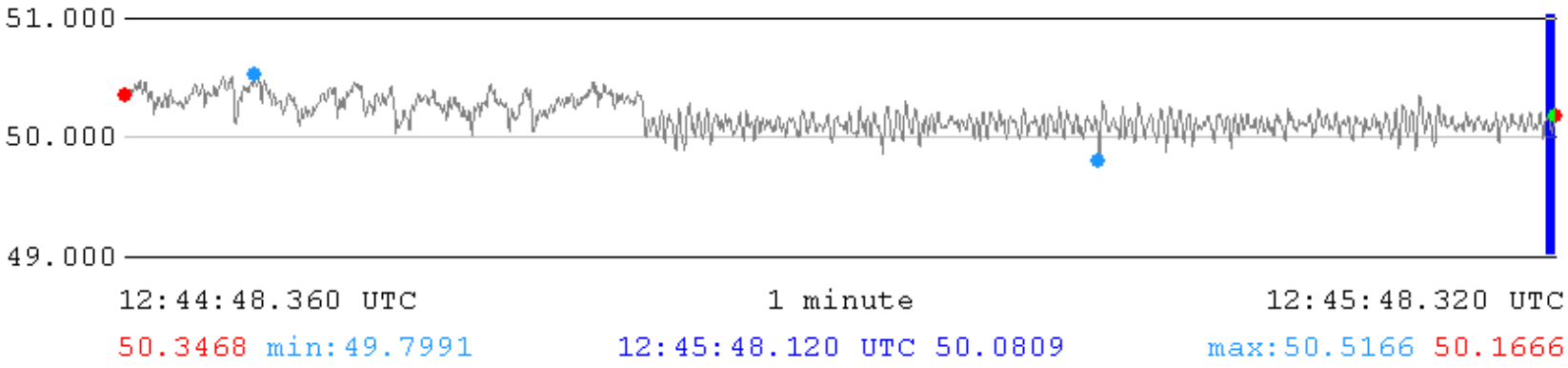
Matching the measurement chain to the application.

A VSG field test demonstration - @ Cheia, Romania
Isolated network algorithm test





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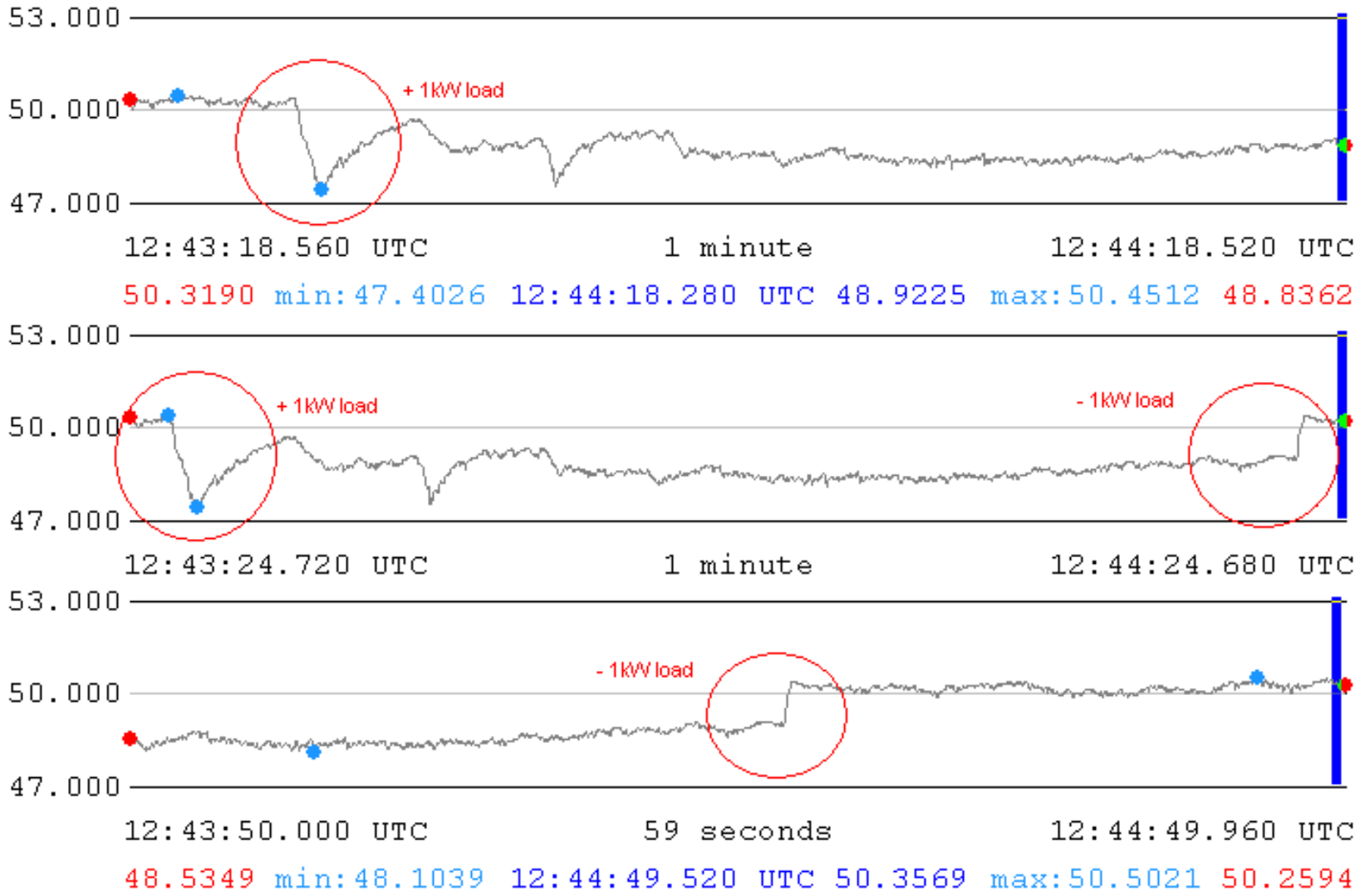
Matching the measurement chain to the application.

A VSG field test demonstration - @ Cheia, Romania
Isolated network algorithm test



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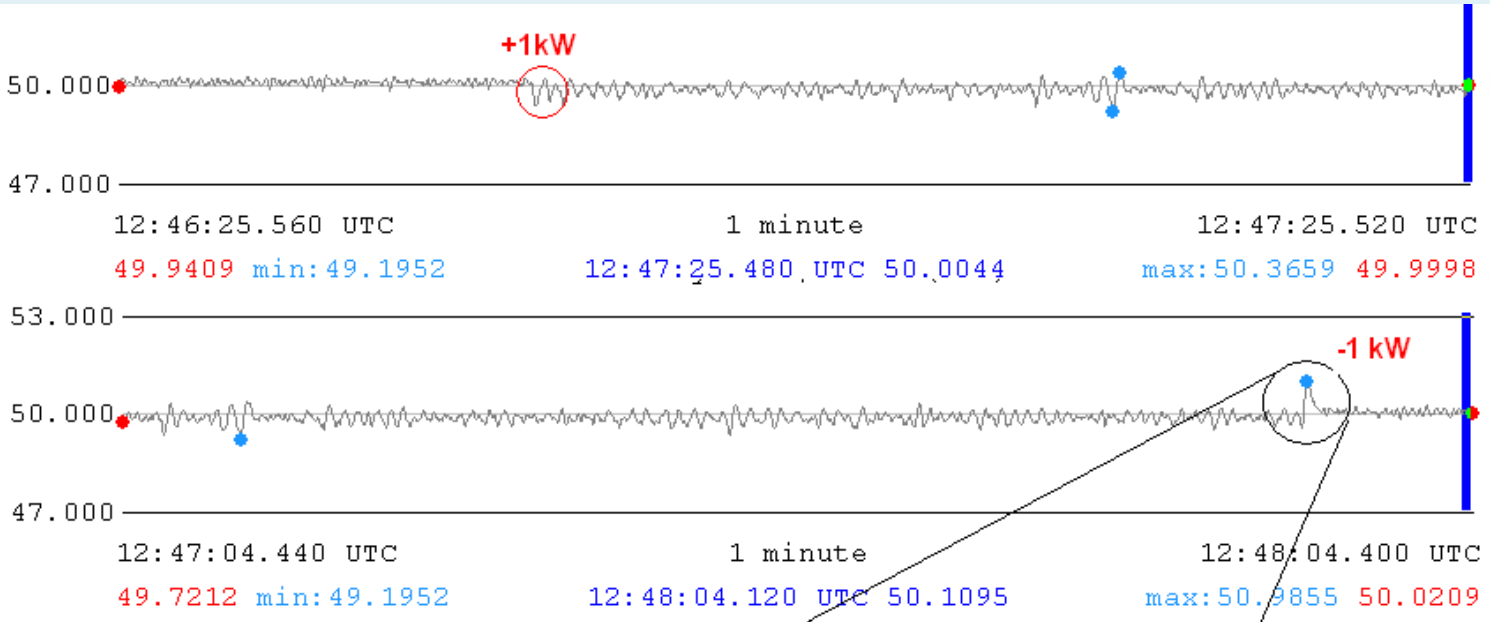
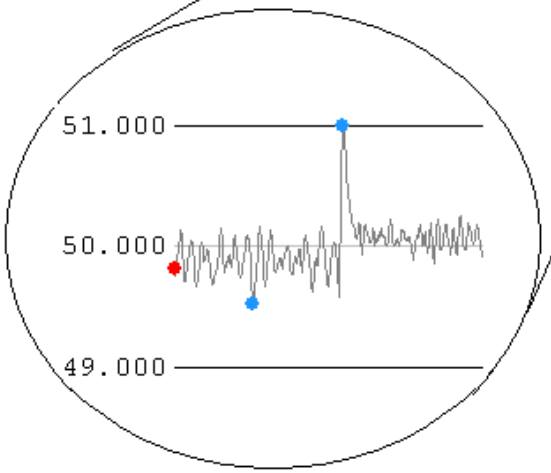
Matching the measurement chain to the application.

A VSG field test demonstration - Isolated network algorithm test



$$I_{sp} = \frac{K_1\left(\frac{1}{2T_h}\cdot J\cdot\frac{1}{2T_h\cdot T_a}\right)+K_2\cdot\frac{1}{2T_h}}{U_{DC}}$$



$$u(I_{sp}) = \sqrt{\left(\frac{\partial I_{sp}}{\partial T_h}\right)^2\cdot u^2(T_h)+\left(\frac{\partial I}{\partial U_{DC}}\right)^2\cdot u^2(U_{DC})}$$

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Thank you for your attention!

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