



MICHIGAN STATE UNIVERSITY

A Philosophical Reflection on Opportunities and Challenges Related to Smart Grid Developments

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Where innovation starts

Acknowledgments

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- R. C Dugan, M. F McGranaghan, S. Santoso, W. Beaty, Joydeep Mitra, Material from M. Bollen, A. Emanuel, J. Arrilagga, G. Chang, N. Mohan, S. Cobben, Leonardo Energy, EPRI, Sandia National Laboratory. Personal Notes and unpublished material from P.F. Ribeiro - Other references - - - include IEEE, ENERNEX, DOE, IEC and CIGRE Working Groups Discussions and Documents
- Some viewgraphs have been modified to emphasize certain aspects.

Outline

- ✓ A Bit of Philosophy
- ✓ Introduction
- ✓ What is a Smart(er) Grid?
- ✓ Impact of MG-DG-DER-RES (Smart Grids)
- ✓ Implications on Signal Measurement
- ✓ Challenges and Opportunities
- ✓ Research and Development Directions
- ✓ Politics and Economics
- ✓ Personal Notes

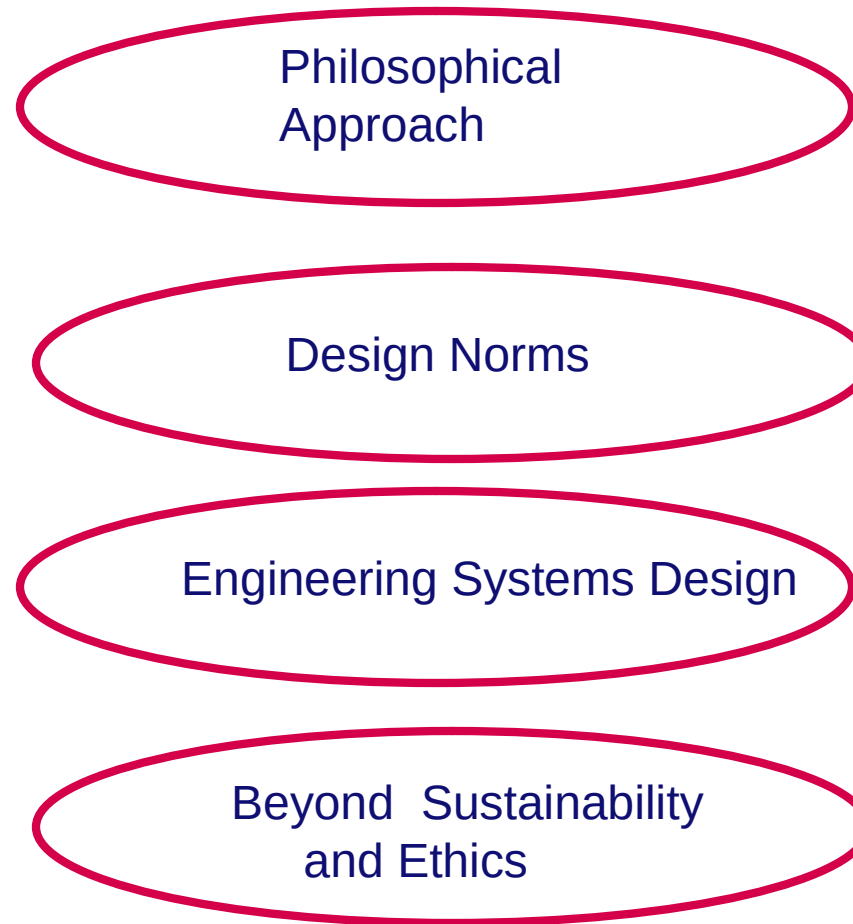
A Bit of Philosophy

When my friend Marcio Friere asked me to borrow my Halliday and Resnick physics' book in 1971 and in exchange offered me a philosophy textbook I did not understand it, and even protested: 'what does philosophy have to do with engineering?' My friend replied : 'everything – we will never be good engineers without understanding the task of philosophy in engineering.' It took me several years to realize what Marcio had said, and 39 years later all I can say is that exchange of words brought another dimension to my perspective of engineering and for which I am profoundly grateful.

Since then I keep hearing from **colleagues and students the similar reaction I had as an immature freshman. The reality is that we easily forget that procedures and the validity of rational thought and argument are presuppositions on which scientific and engineering thought and experiment rest upon, but they are themselves not “scientific” or practical engineering statements. They are philosophical statements.**

The Big Picture of Engineering Design

Ever Increasing Complexity



A Bit of Philosophy

Science and engineering depends fundamentally on philosophy for the validity of its terms and procedures and the determination of the uses to which scientific and engineering knowledge will be put.

The classical affirmation that only factual statements have validity and legitimacy is not only dogmatic (besides arrogant) but self-contradictory, since the statement itself is not factual.

Therefore, we should avoid the mistake to affirm that “what is not in principle observable is not in fact in existence.” Truth, meaning, purpose, etc, are none of them scientific facts.

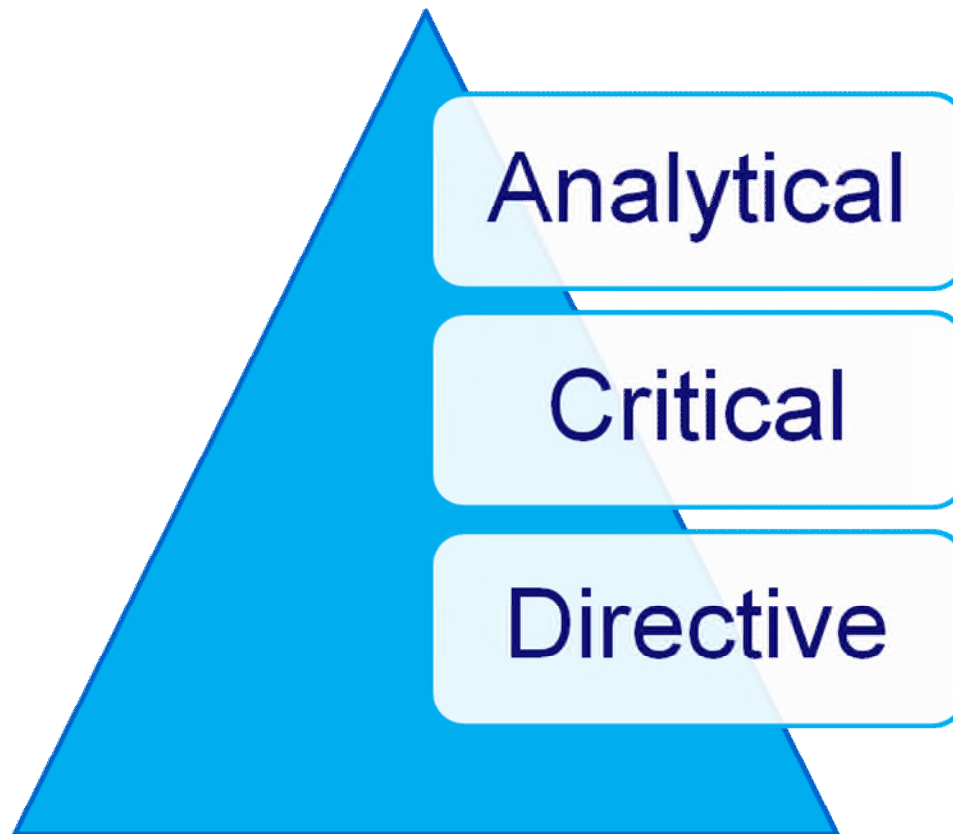
A Bit of Philosophy

“Not all that is ‘scientific’ is necessarily true; and not all that is ‘true’ is necessarily ‘scientific’!”

Perhaps if we think in these terms we may see after all that global warming and other possible consequences of engineering and technological development have a deeper cause: our inability to think in broader terms.

We need to design and implement engineering in such way that promotes a sustainable environment. And for that we need to think globally, integrally: philosophically.

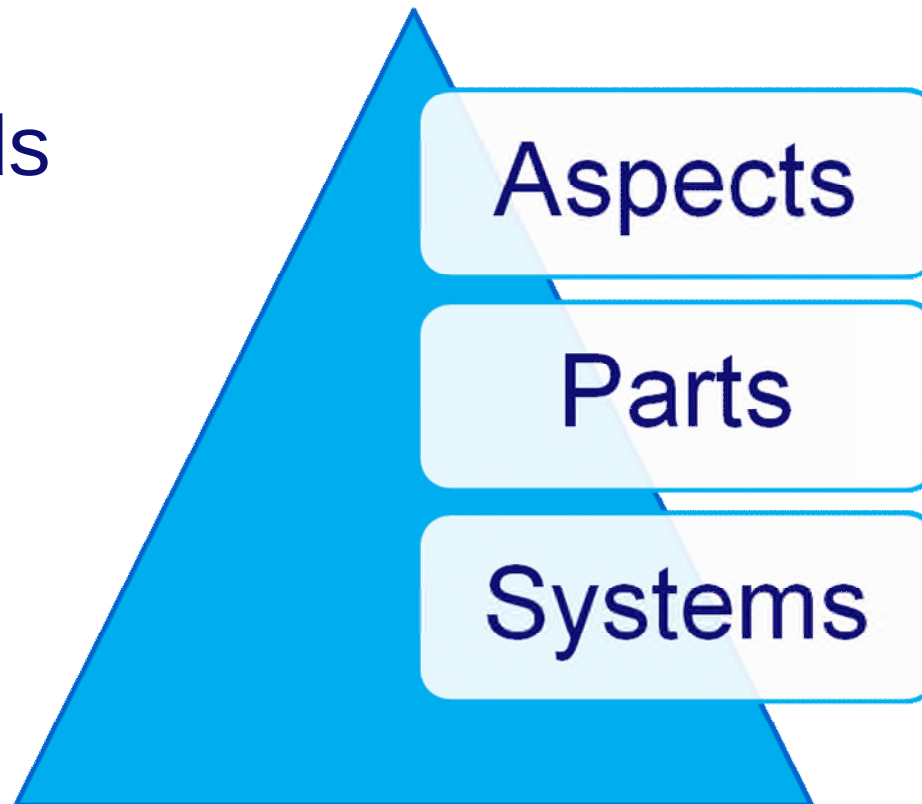
Functions of Philosophy



A Bit of Philosophy

Engineering
Design Needs
to Integrate
Them All

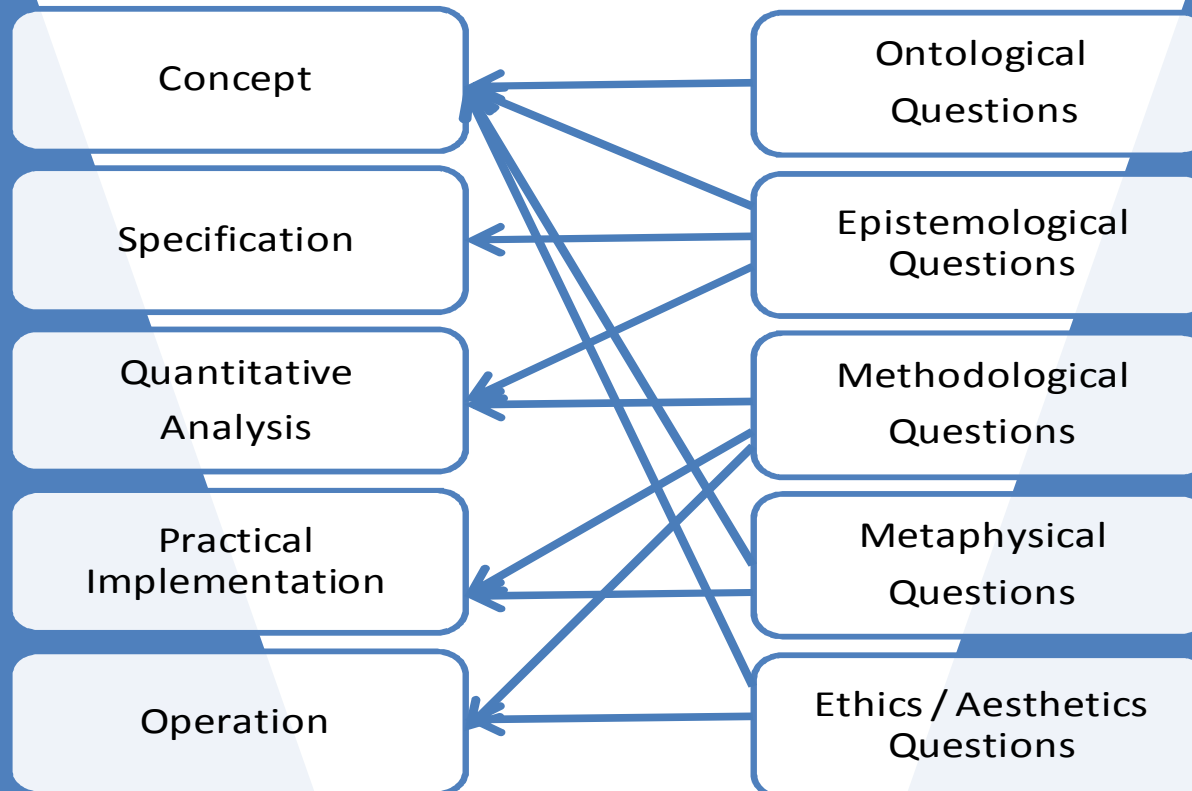
Complex
Systems



Engineering Design and Philosophical Questions

Engineering / Technology Process

Philosophy Process Questions



Fields of Philosophy

Ontology - what exists and the essence of things, what makes technology different from nature? When do we call something technological or artificial, and when do we call it natural?

Epistemology - the nature of knowledge., what do we mean when we say we know that energy is lost when electricity flows over metallic conductors?

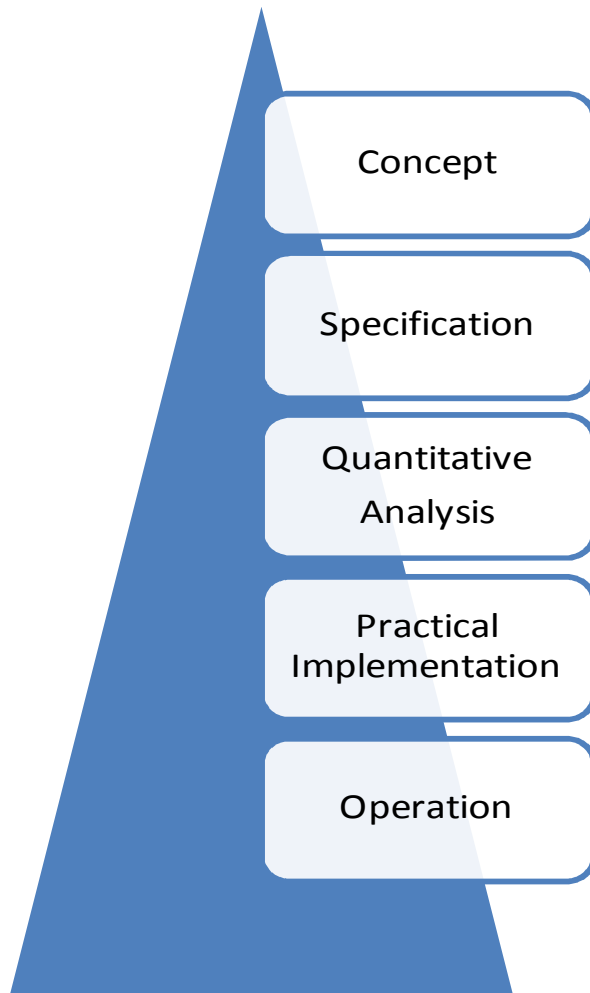
Methodology – the ways, means and methods with which tasks and goals can be achieved.

Metaphysics – the vision of reality, related to one's worldview, purposes and meaning. Although it is not necessarily related to religion, it is certainly related to faith and core beliefs.

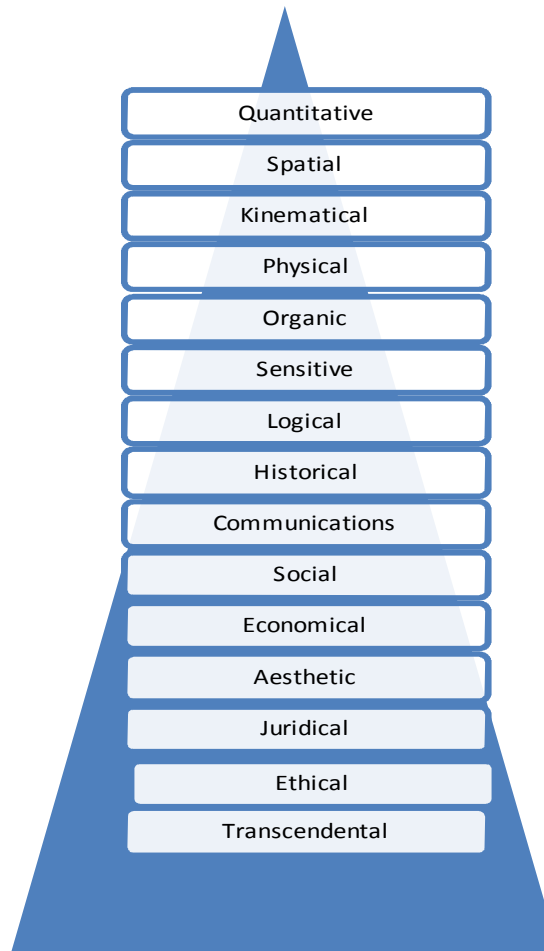
Ethics and Aesthetics – values and logical analyses of ethical dilemmas

Engineering Design Process, Factors and Fundamental Aspects

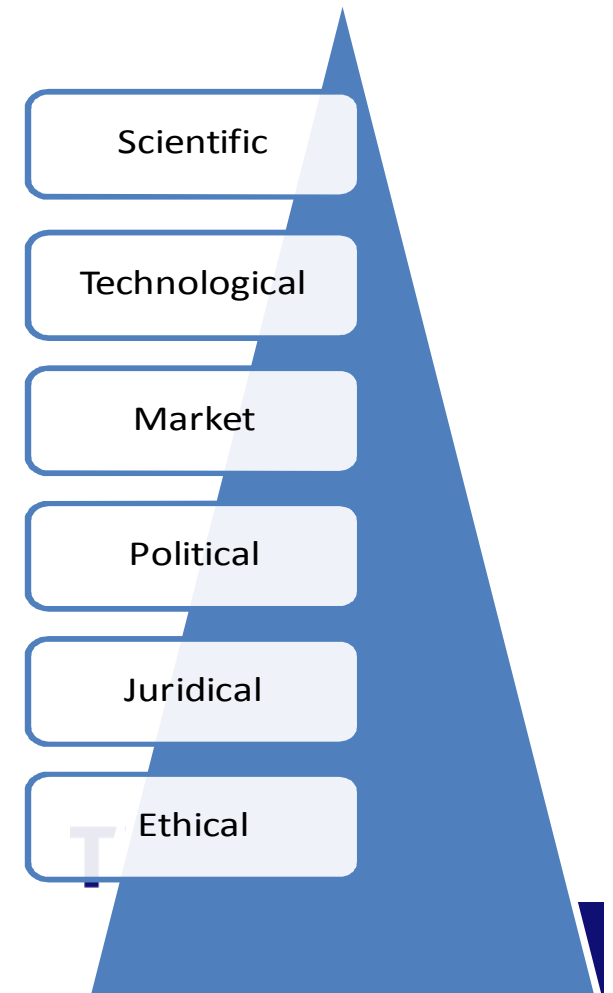
Engineering Process



Fundamental Functions and Aspects



Design Factors



Introduction

The Context



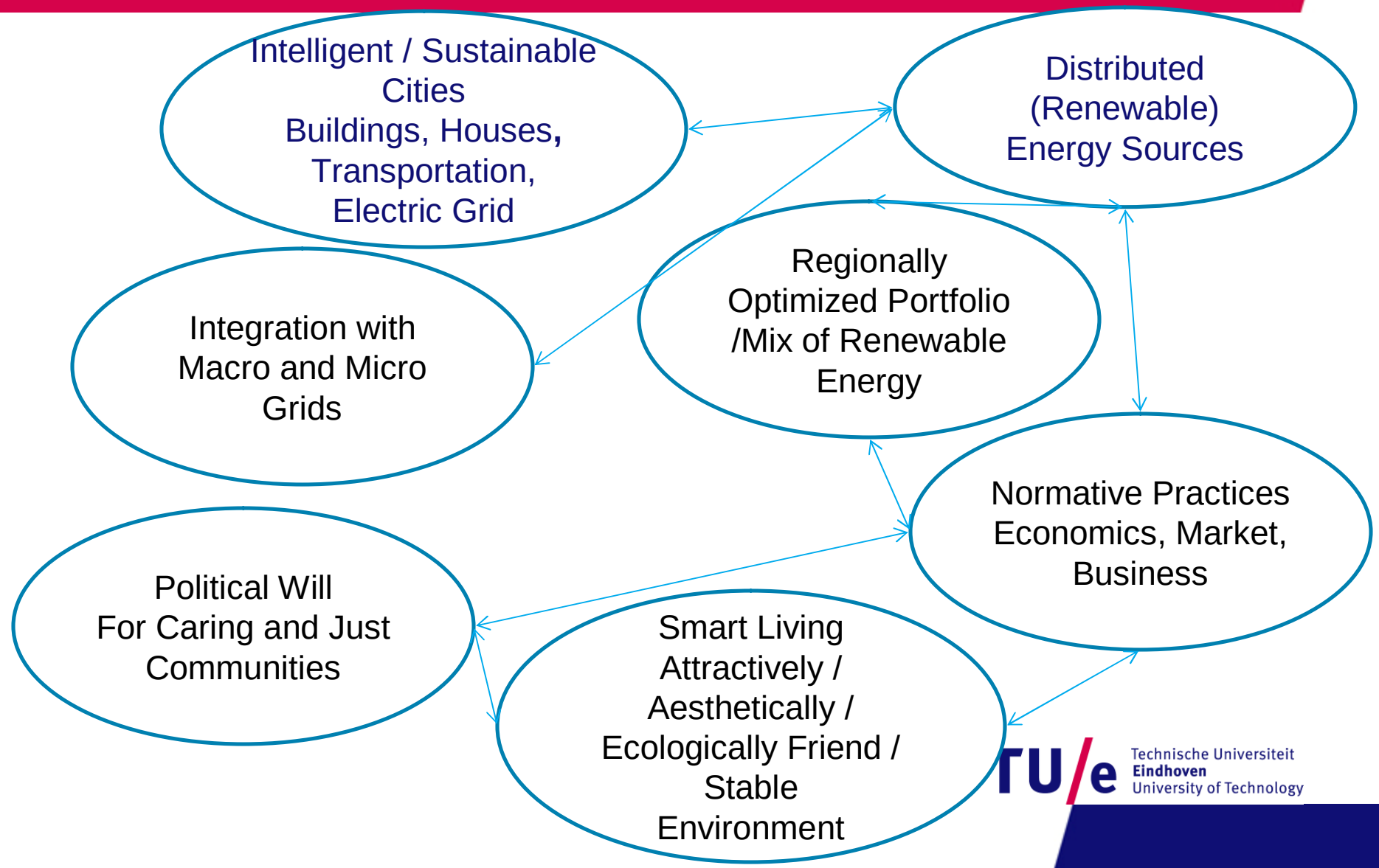
One of the most used terms in the utility industry in the last decades is “**DEREGULATION**” and which has caused deep changes in way power systems are designed and operated.

The centralized and verticalized grid model based on electromechanical components, will be substituted by distributed and unbundled model with digitalized components. Generation, control and measurement will suffer changes and impacts with this new model. Power systems and power quality paradigms will be broken.

Independently of political actions that establishes commercial objectives and issues to the utilities and customers, the new model is being constructed and implemented with the objective to achieve higher reliability, quality, lower costs, etc.

This is the context in which MacG-MicG-DG-DER-RES and SMART GRIDS are being developed.

The Big Picture For Smart Grids: Smarter Living



Introduction

Great Expectations

"a new smart grid ... will save us money, protect our power sources from blackout or attack, and deliver clean, alternative forms of energy to every corner of our nation."

President Obama in an address at the George Mason University, Fairfax, VA on Jan 8, 2009¹

2009 - banner year for Smart Grid; Year of the Smart Grid for VCs
Smart Grid News, www.smartgridnews.com

During the next 4 years, KEMA anticipates \$16 billion in Smart Grid incentives for driving Smart Grid projects worth \$64 billion. The will result in direct creation of 280,000 new positions across various categories, of which more than 150,000 will be created by the end of 2009²

¹ Environment News Service. "Obama vows dramatic action towards a greener economy."
[Online] {Available} <http://www.ens-newswire.com/ens/jan2009/2009-01-08-01.asp> (Sep 2009)

² Kema Inc. "The U.S. Smart Grid Revolution KEMA's Perspectives for Job Creation," Report prepared for Gridwise Alliance, Dec 08 .

Introduction

The Path Toward the Smart Grid: Thus Far

The Electricity Advisory committee (EAC) recommended to DoE to create a *Smart Grid Program Office* in Dec 2008 ^[3]

US Congress includes ~ \$4.5B for Smart Grid deployment ^[4]

Several smart grid projects underway across the US - microgrids, AMI, smart workforce developments, standard developments, renewable energy deployments, etc.

NIST is the national coordinator for Smart Grid Interoperability
Released framework and roadmap for SG interoperability Stds. on Sep 24, 2009

IEEE PES created a *Transactions on Smart Grid*

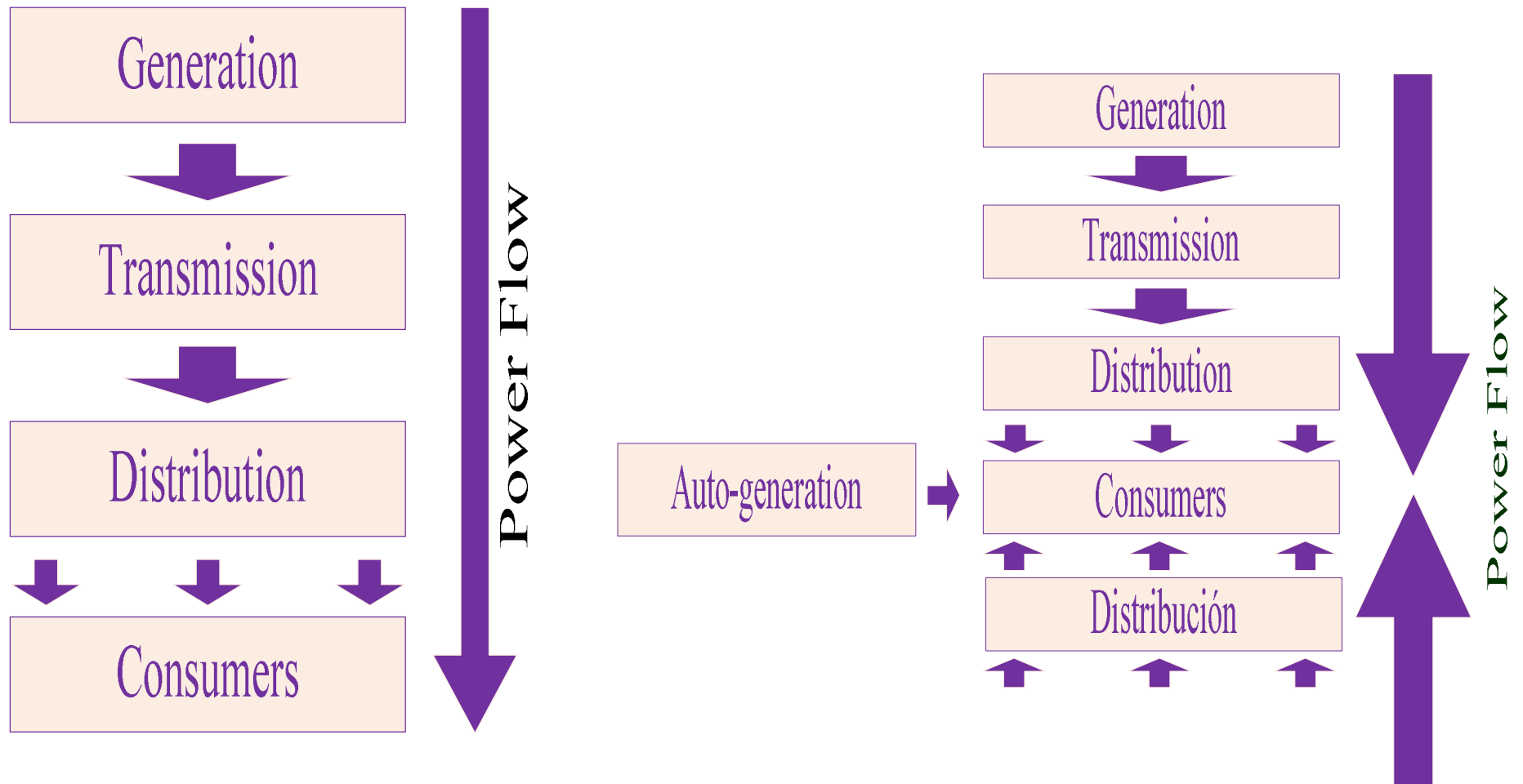
³ Electricity Advisory Committee, United States Department of Energy, "Smart Grid: Enabler of the New Energy Economy," [Online] {Available}:
<http://www.oe.energy.gov/DocumentsandMedia/final-smart-grid-report.pdf> (Jan. 2009)

⁴ 111th Congress of USA, "American recovery and reinvestment act of 2009," [Online] {Available} http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=111_cong_bills&docid=f:h1enr.pdf (Feb 2009)

Introduction

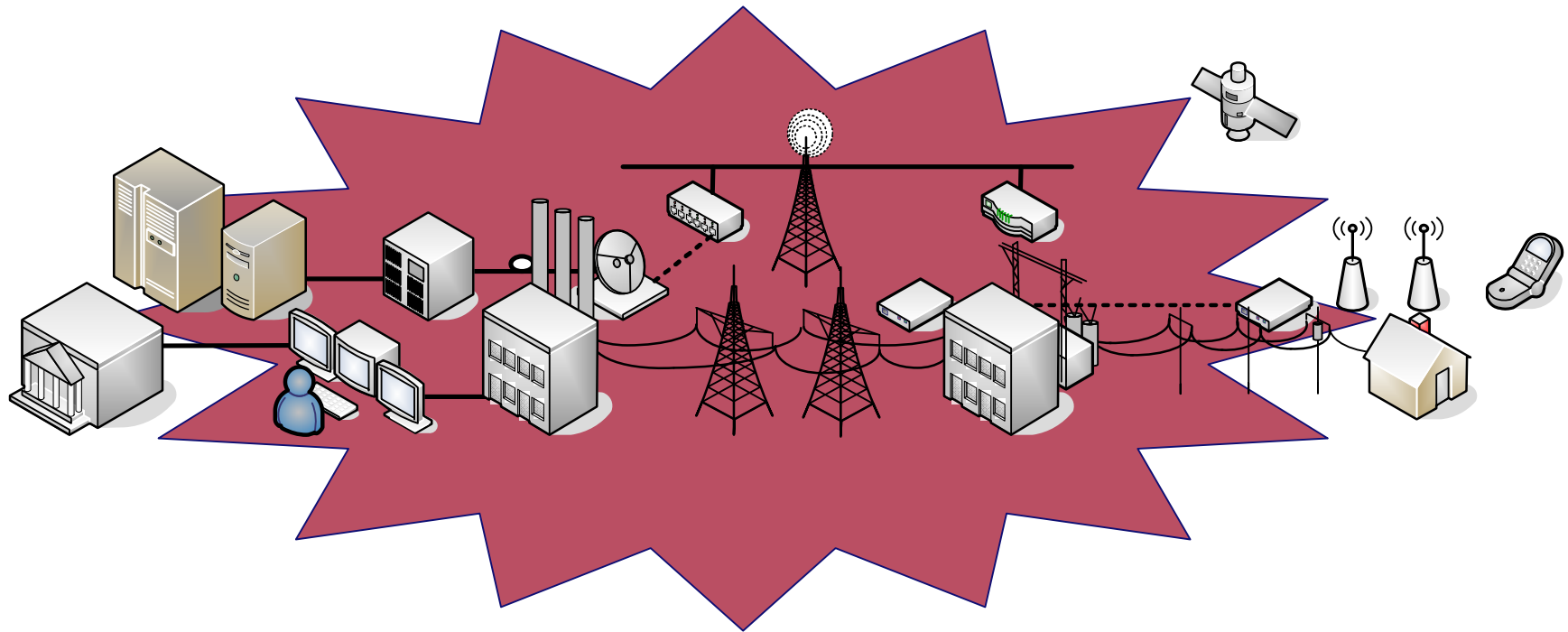
First, something about electricity network of the future

Electricity network of the future



<i>Characteristic</i>	<i>Today's Grid</i>	<i>Smart Grid</i>
Enables Consumer Participation	Consumers are uninformed and non-participative with the power system	Informed, involved and active consumers – DR and DER
Accommodates Generation/Storage	Dominated by central generation – many obstacles exist for DER interconnection	Many distributed energy resources with “plug and play” convenience – focus on renewables
Enables New Markets	Limited wholesale markets, not well integrated – limited opportunities for consumers	Mature, well-integrated wholesale markets, growth of new electricity markets
Meets PQ Needs for 21st Century	Focus on outages – slow response to PQ issues	PQ a priority with a variety of quality/price options – rapid resolution of issues
Optimizes Assets & Operates Efficiently	Little integration of operational data with asset management – business process silos	Greatly expanded data acquisition of grid parameters – deeply integrated with asset management processes
Self Heals	Responds to prevent further damage – focus is on protecting assets following fault	Automatically detects and responds to problems – focus on prevention, minimizing impact to consumer
Resists Attack	Vulnerable to malicious acts of terror and natural disasters	Resilient to attack and natural disasters with rapid restoration capabilities

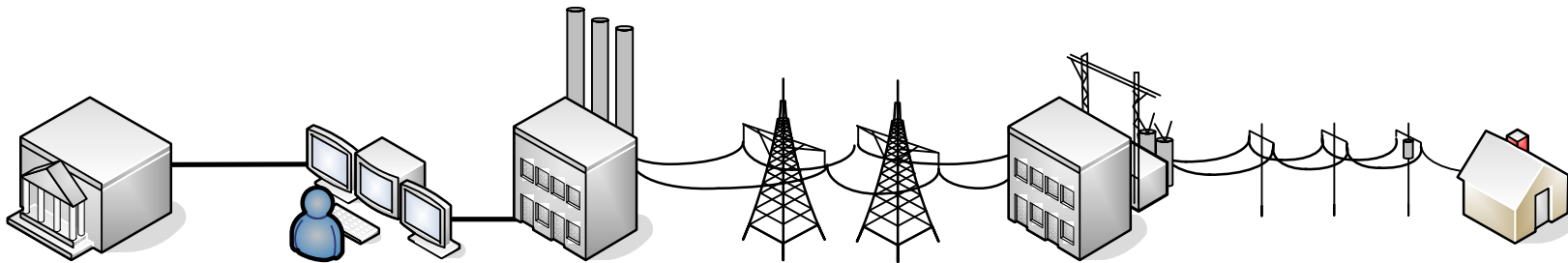
What is a Smart Grid, Really?



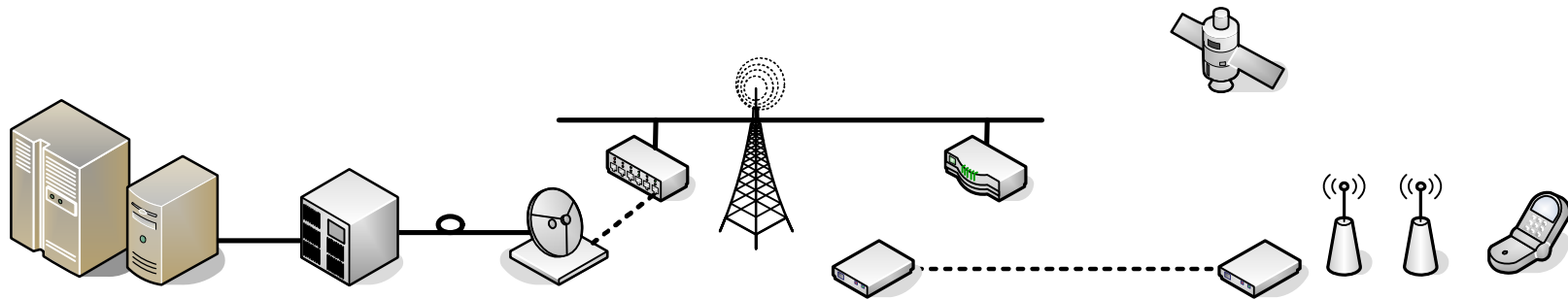
Nobody Really Knows!

What is a Smart Grid, Really?

Merging Two Smart Infrastructures



Electrical (Smart) Infrastructure



Controls and Communications (Smart) Infrastructure

What is a Smart Grid, Really?

Smart Grids Definitions

- ✓ **National Electrical Manufacturers Associations**
 - ✓ The basic concept of Smart Grid is to add monitoring, analysis, control and communication capabilities to the national electric grid in order to improve reliability, maximize throughput, increase energy efficiency, provide consumer participation and allow diverse generation and storage options.
- ✓ **IEC**
 - ✓ The Smart Grid is the concept of modernizing the electric grid. The Smart Grid comprises everything related to the electric system in between any point of Generation and any point of Consumption. It also includes the coupling effects with other forms of energy (thermal storage, etc...)
- ✓ **Smart Grids is basically the concept of making the power grid “SMARTER”**

European Definition

- Although there is no standard global definition, the European Technology Platform SmartGrids defines smart grids as electricity networks that can intelligently integrate the behavior and actions of all users connected to it - generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies.

-

European Definition

- A smart grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies in order to:
- Better facilitate the connection and operation of generators of all sizes and technologies;
- Allow consumers to play a part in optimizing the operation of the system;
- Provide consumers with greater information and options for choice of supply;
- Significantly reduce the environmental impact of the whole electricity supply system;
- Maintain or even improve the existing high levels of system reliability, quality and security of supply;
- Maintain and improve the existing services efficiently;
- Foster market integration towards European integrated market.

USA Perspective

- The smart grid uses technological advancements to achieve its principal goals, which are summarized below.
- Enables active consumer participation:
- Accommodates all generation and storage options:
- Enables new products, services, and markets:
- Provides power quality for the digital economy:
- Optimizes asset utilization and operates efficiently:
- Anticipates and responds to system disturbances:
- Operates resiliently against attack and natural disaster:

Smart Grid Benefits

The benefits resulting from the implementation of Smart Grid can be categorized into the following areas:

BENEFITS TO CONSUMERS:

- Allow consumer choice
- Increase consumer information
- Reduce cost
- Engage consumers
- Provide environmental value

BENEFITS TO UTILITIES:

- Increase energy efficiency
- Reduce carbon emissions
- Enable renewable resources
- Increase reliability
- Improve operational efficiency

BENEFITS TO THE ENVIRONMENT:

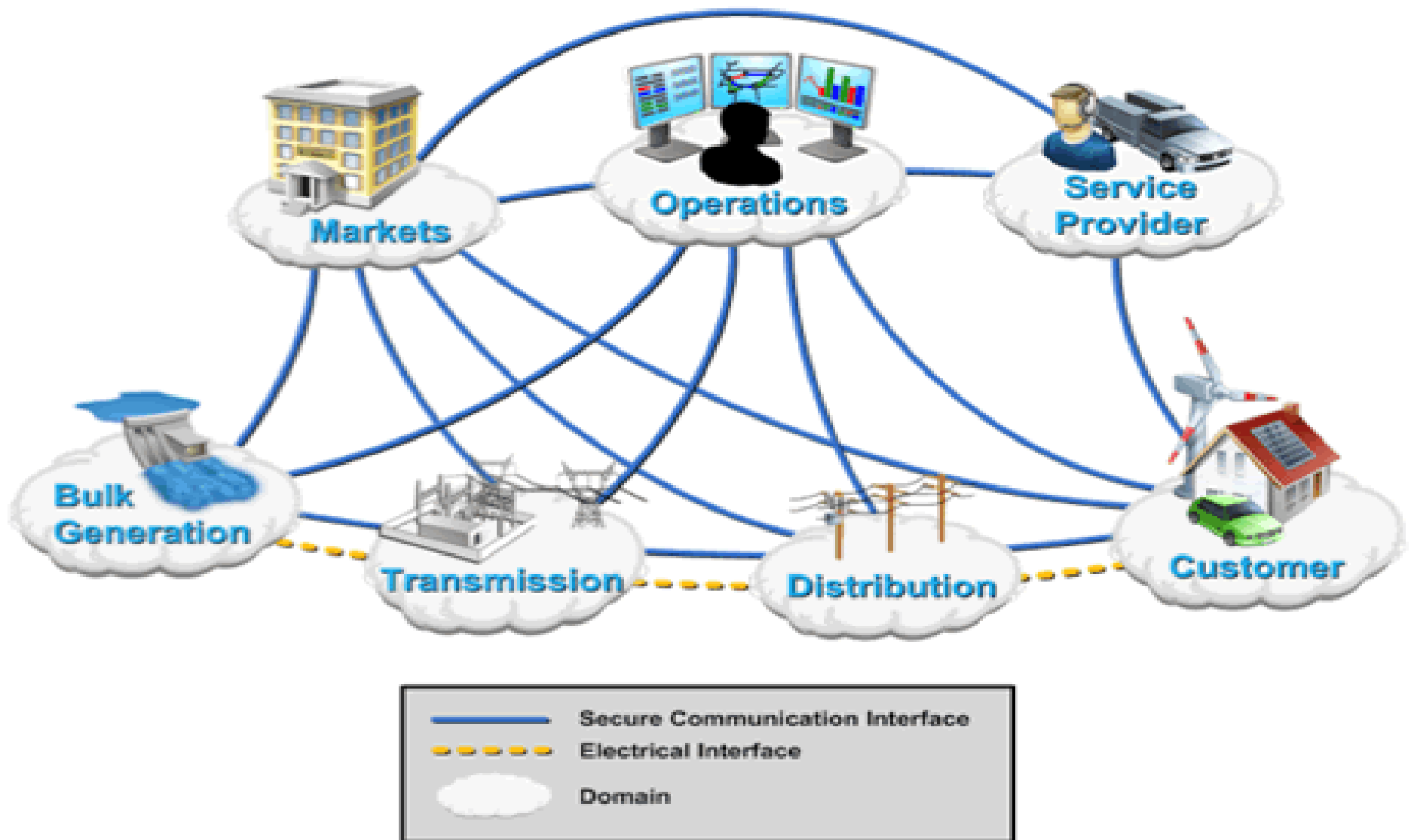
- Carbon emission reduction
- Renewables integration
- Delaying new power plants
- Incentives for conservation
- Demand response for managing air pollution

BENEFITS TO THE ECONOMY:

- Green jobs (280,000 by 2012)
- Higher value jobs, retention
- Investment in entrepreneurs
- New manufacturing base
- Global competitiveness

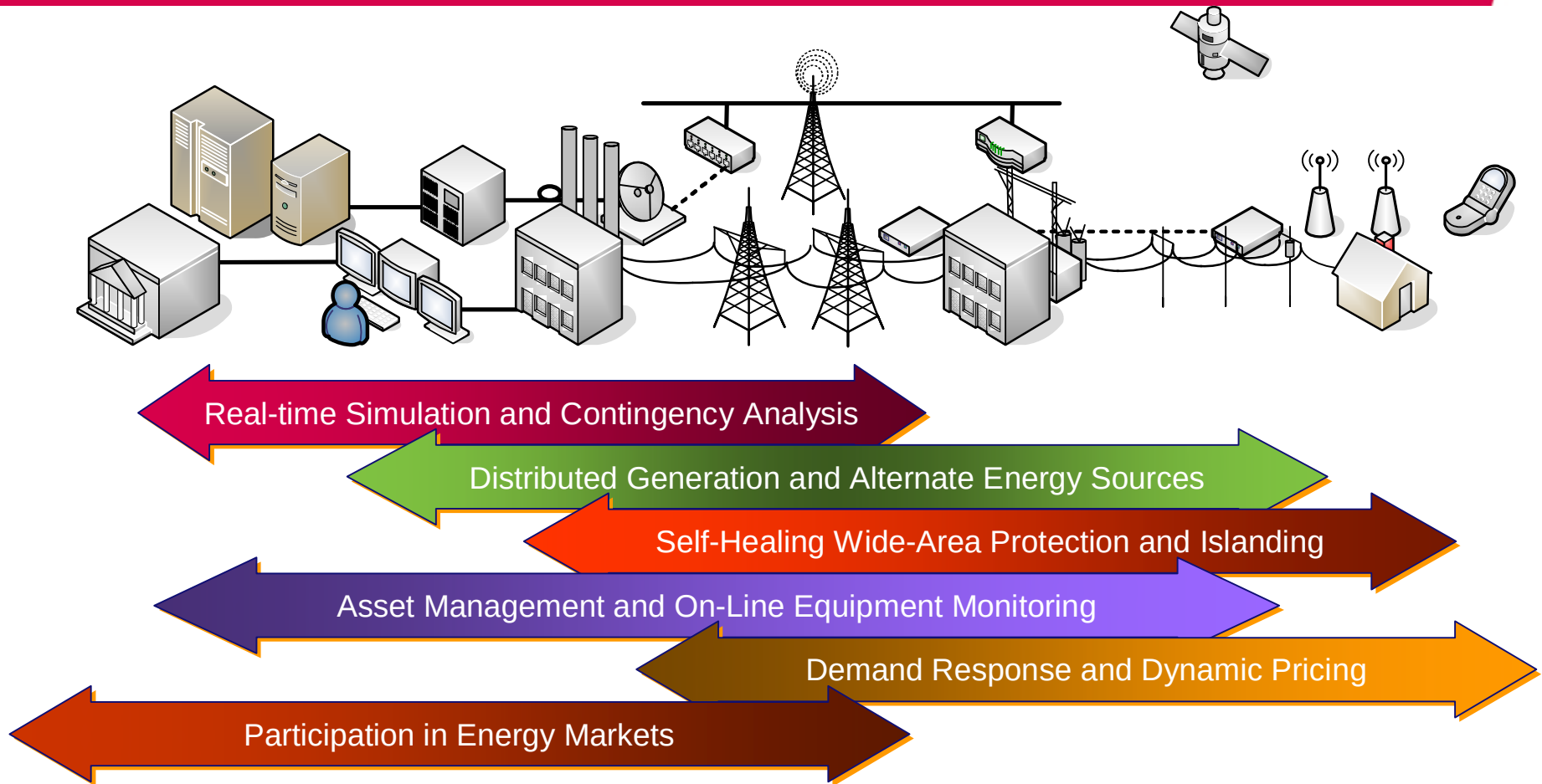
Smart Grid: Overall View

Parts and Systems



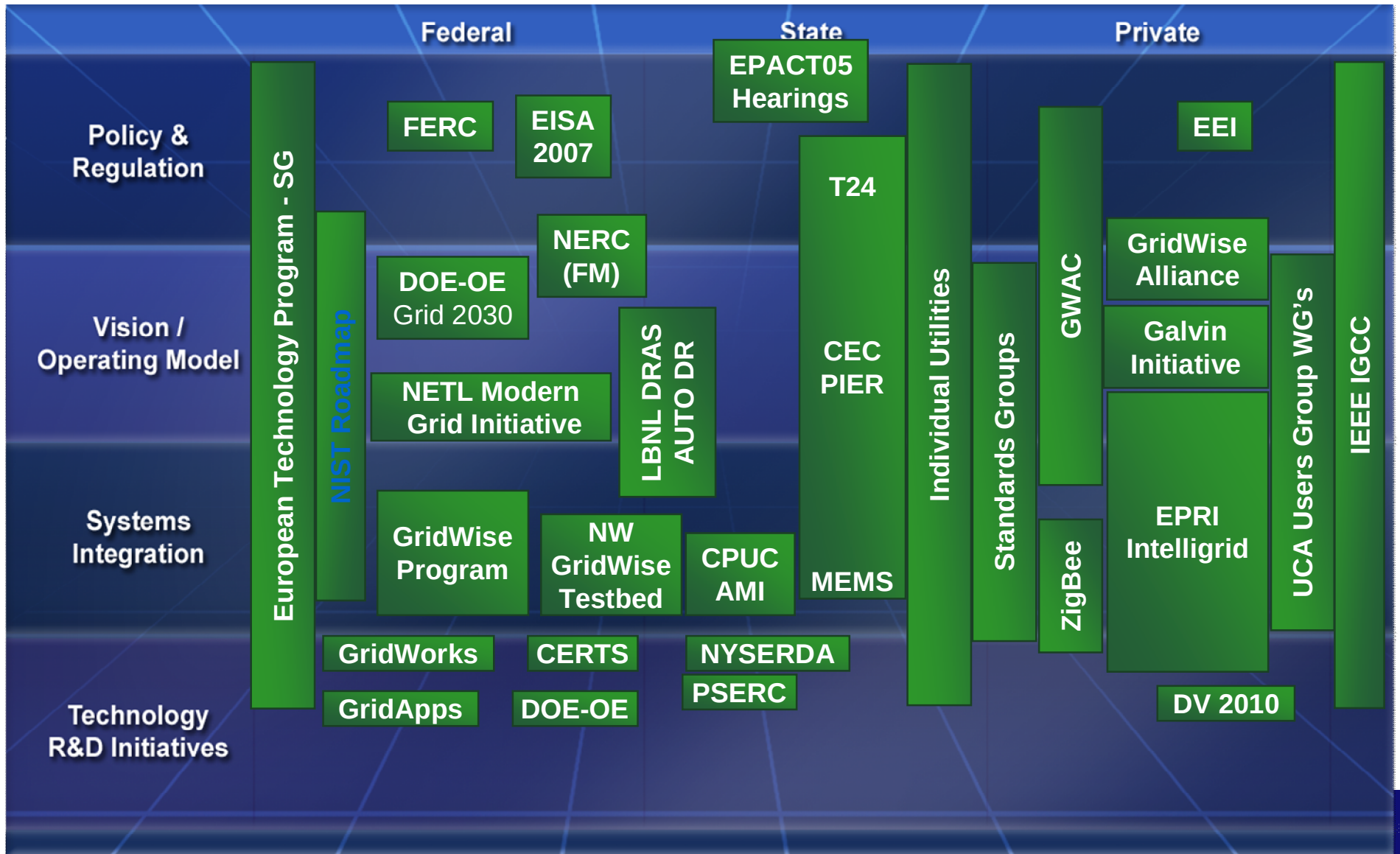
What is a Smart Grid, Really?

Smart Grid Applications



**Shared Information – Continuously Optimizing
Intelligent Responses!**

Smart Grid Activities



Developers of the Modern Grid

- **Grid Modernization: a *Non-Trivial* Task**
- **Each organization has a constituency, but:**
 - **Visions are Aligned**
 - **Goals are Remarkably Consistent**
 - **Tactics are Complimentary**
 - **Modern Architecture Concepts are Being Developed**
 - **Collaboration is Occurring**

That's great but ...

- **Now the Hard Part: Systems of Systems Engineering**
 - **Scalability** – *lots of stuff*
 - **Reliability** – *its gotta work*
 - **Security** – *don't mess up*
 - **Privacy** – *think about it*
 - **Configuration Management** – *lots of stuff*
 - **Network Management** – *more stuff*
 - **More value through Integration** – *Opportunity!*



“Any competent engineer can glue two systems together and make it work. But it takes sound architecture and good systems engineering practice to make the resulting system scalable, manageable, secure – and oh, yeah... *address the business case.*”

- *Erich W. Gunther,*
EnerNex co-founder

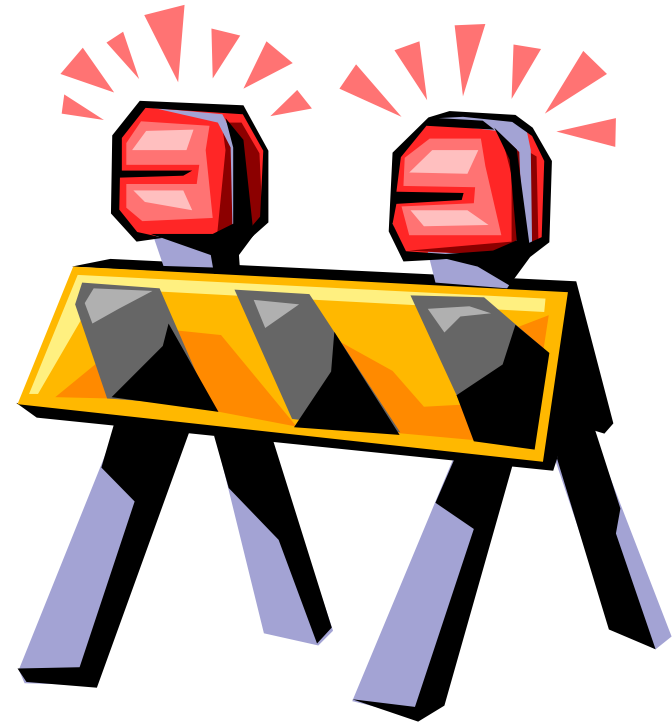
DANGER: Smart Grid Integration without Standards or Architecture

- It is not sufficient just to integrate systems haphazardly
- There must be an overarching plan, or blueprint
- Otherwise, vital systems integration may be prevented because of:
 - High costs
 - Missing technology

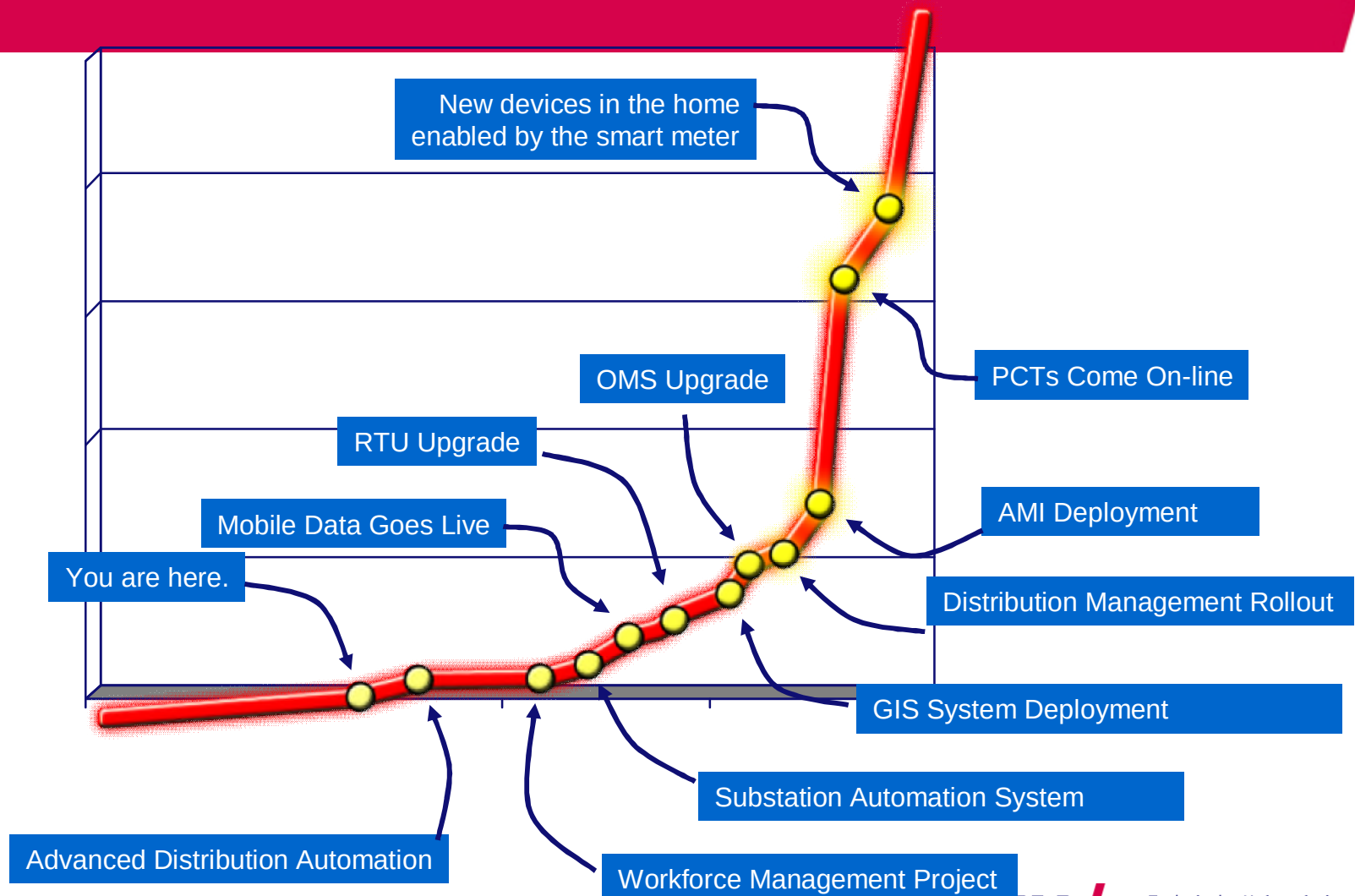


Barriers to Planned System Integration

- *Organizational*
 - Corporate culture
 - Existing policies
 - Departmental “Silos”
 - Lack of human resources
- *Knowledge*
 - Missing applications
 - Missing algorithms
 - Lack of training
- *Systems*
 - Lack of standards
 - Too many “standards” to choose from
 - Missing products and services
 - Not applying formal methodology
- *Business*
 - Lack of policy to use standards
 - Not writing it into RFP’s

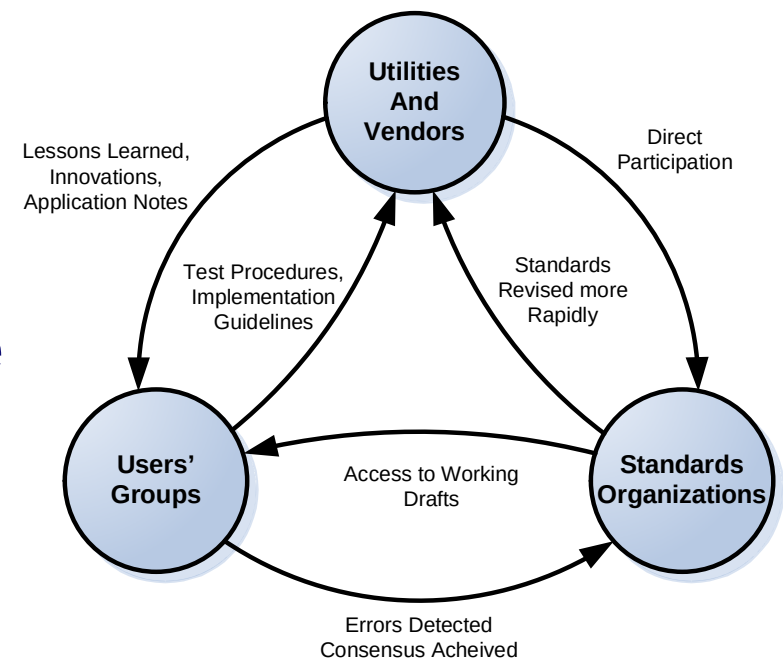


Smart Grid Data Explosion



Why Use Standards?

- Avoid re-inventing the wheel
- Learn from industry best practices
- Specify requirements more easily
- Reduce integration costs
- Prevent single vendor “lock-in”
- Vendors share a much larger market



Standards Roadmap

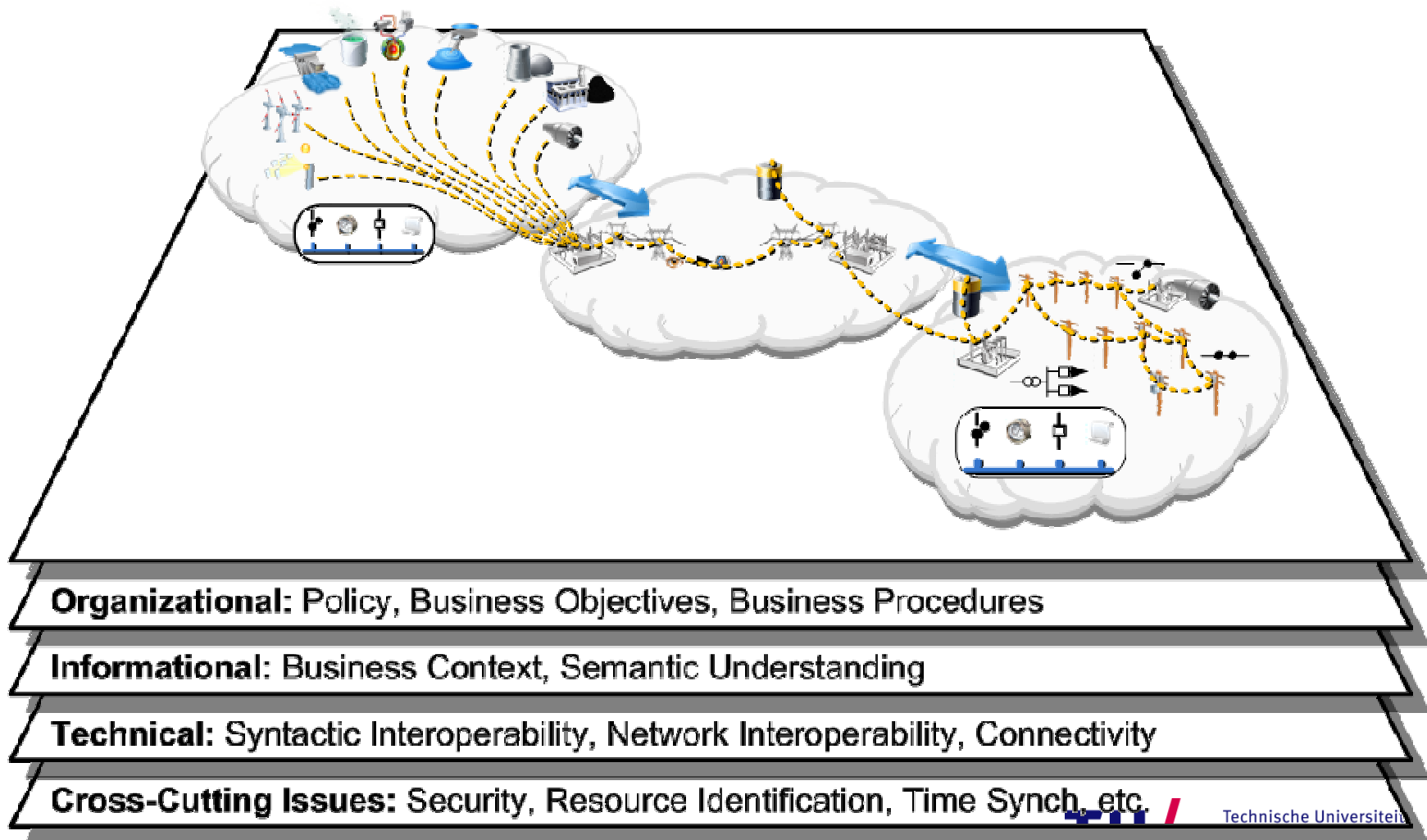
- Capabilities
- Priorities
- Reference Model
- Standards
- Release Plan
- Responsibilities
- Governance
- Testing and Certification



Roadmap Focus Areas

- **Priority applications:**
 - Demand Response
 - Wide-Area Situational Awareness
 - Electric Storage
 - Electric Transportation
- **Additional priority applications:**
 - Advanced Metering Infrastructure
 - Distribution Grid, including Distributed Energy Resource Integration
- **Cross-cutting priorities**
 - Cyber Security
 - Data networking

Interoperability Layers and the Model



What Does the Smart Grid Need?

For the applications of interest, can we agree on:

- **What information is to be exchanged?**
- **What is the data to be named?**
- **Who is permitted to talk?**
- **In what format are messages transmitted?**
- **What frequencies and signals are used?**
- **What the connector looks like?**

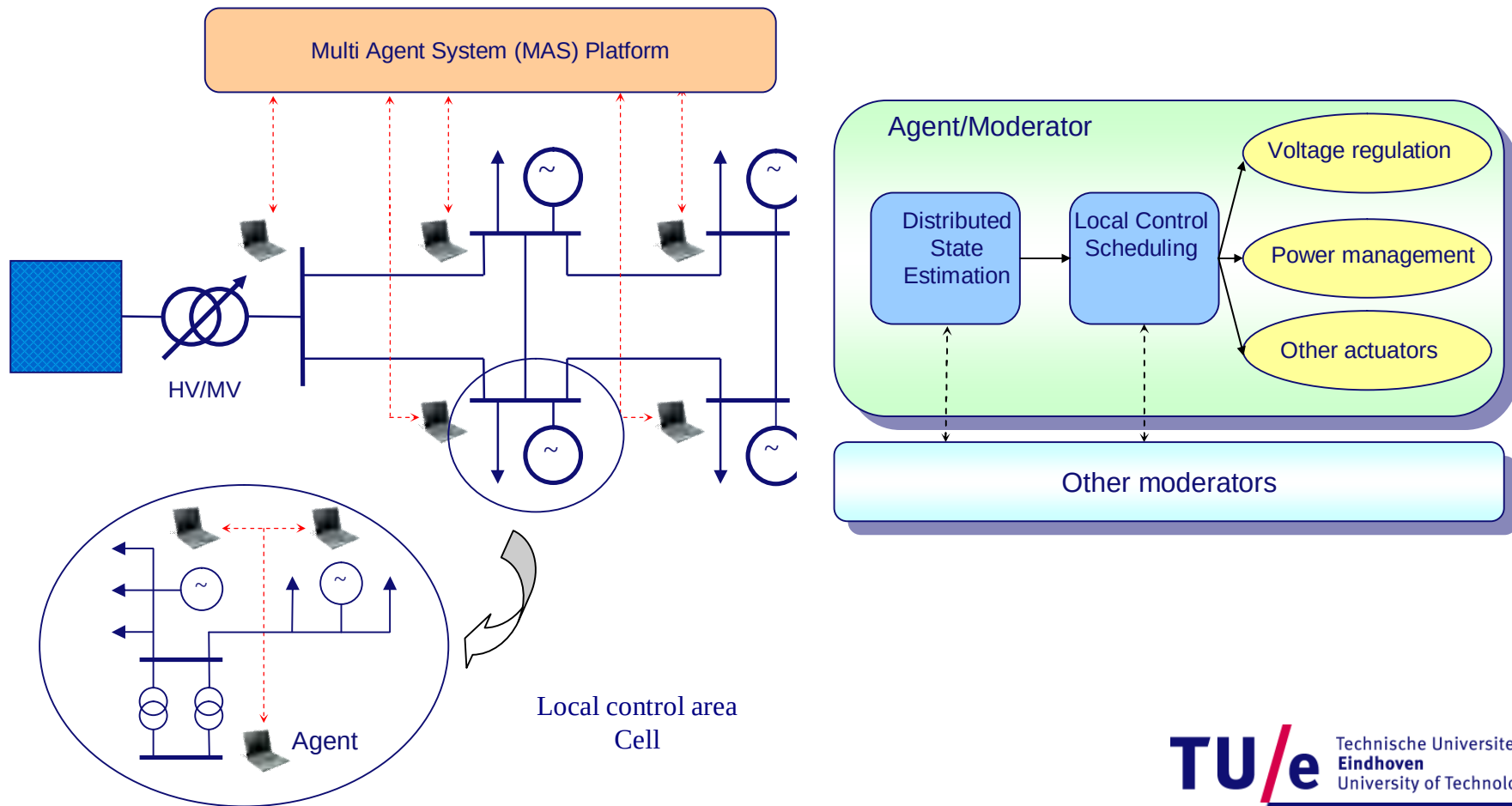
The answers are different for:

- **Different physical areas of the grid**
- **Different functions to be performed**

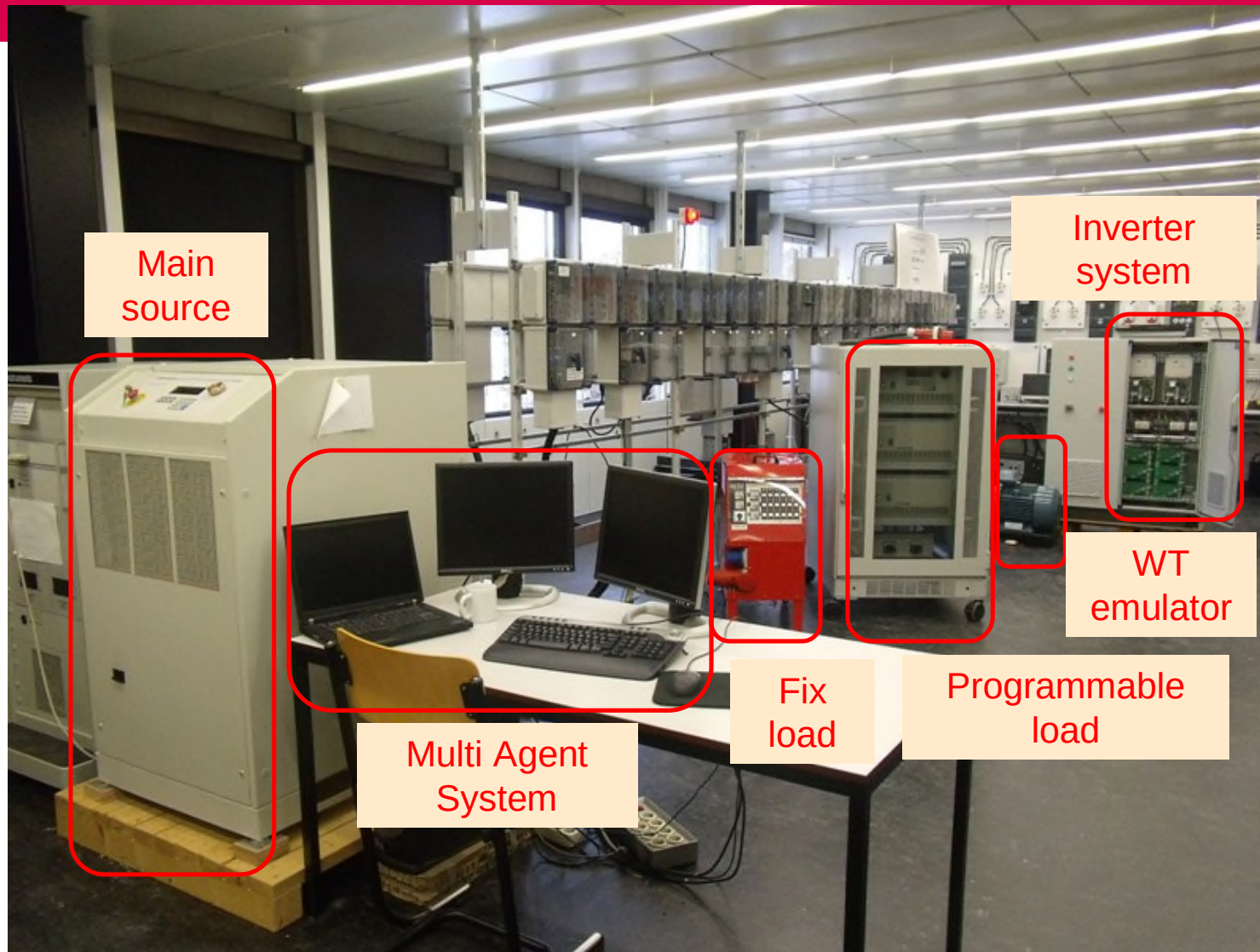


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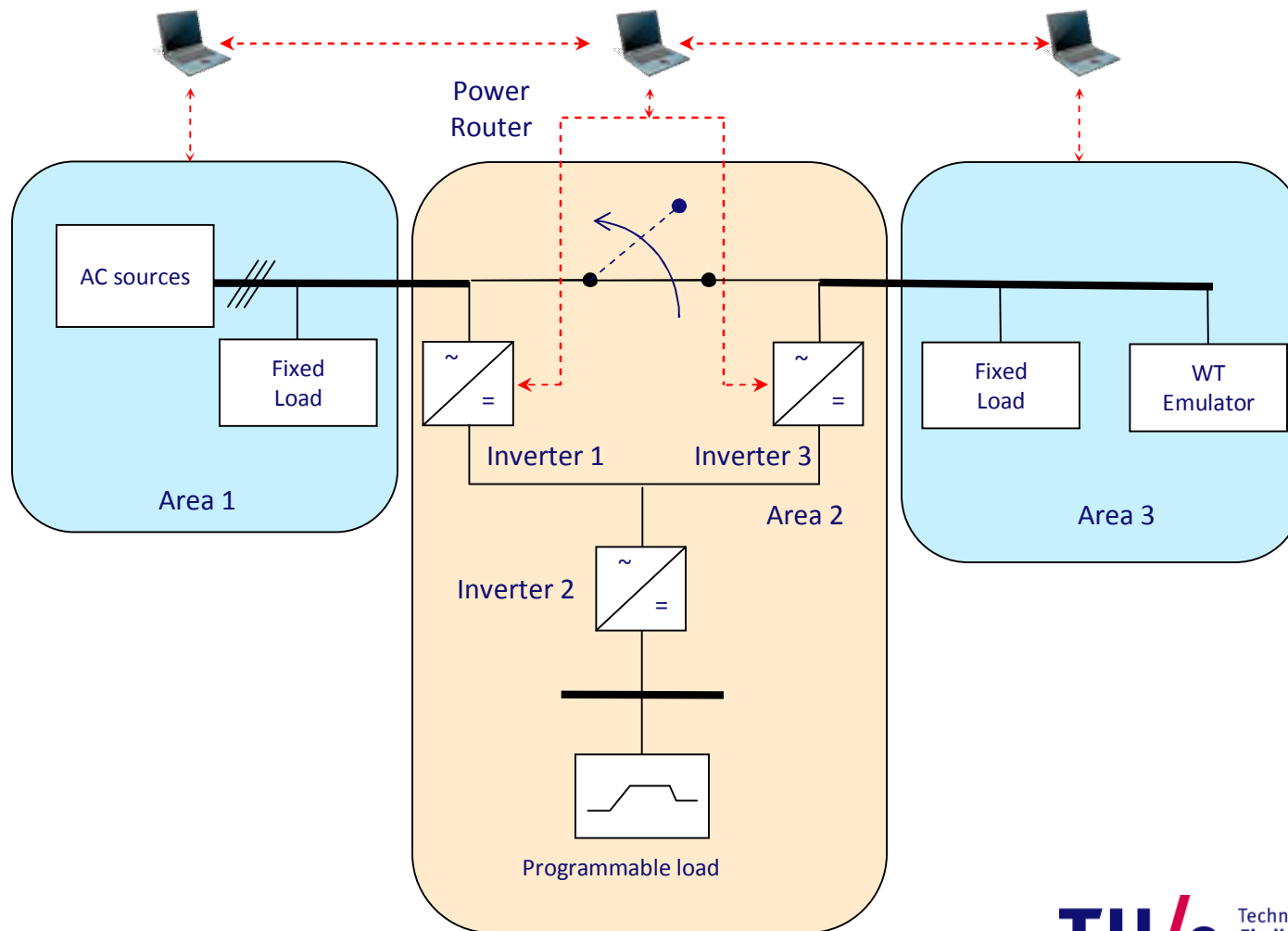
An example: Active Distribution Network



TU/e – Lab Set-up

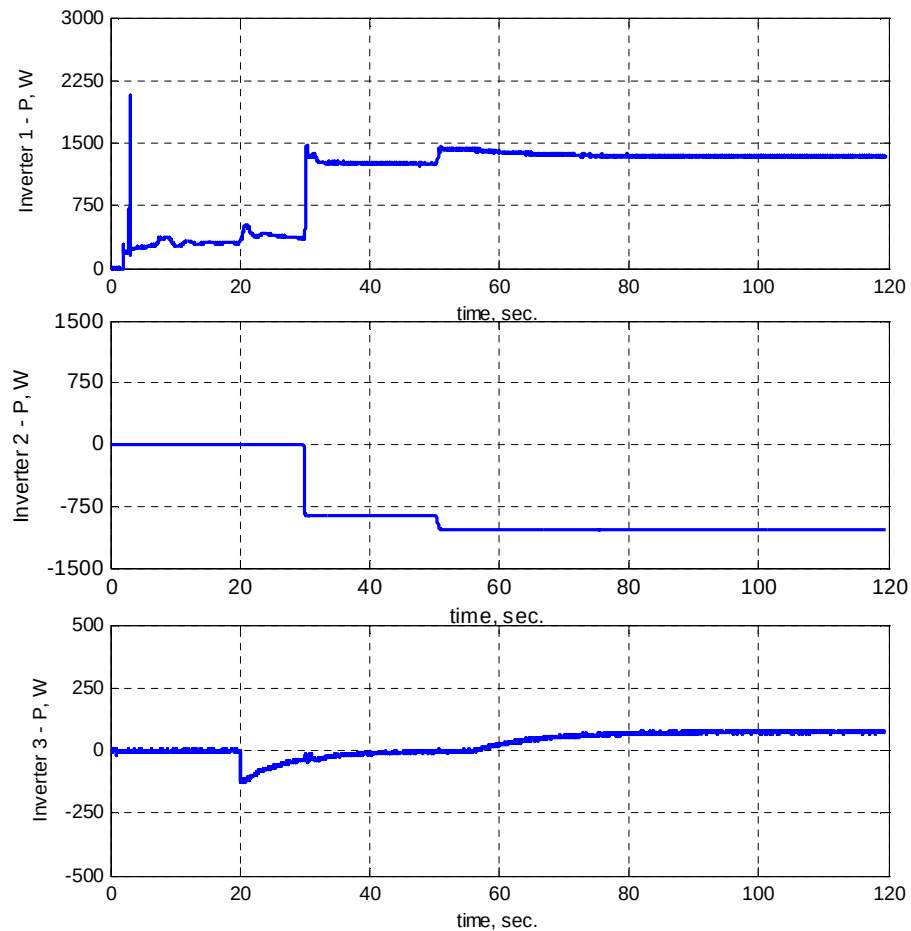


TU/e Lab Set-up

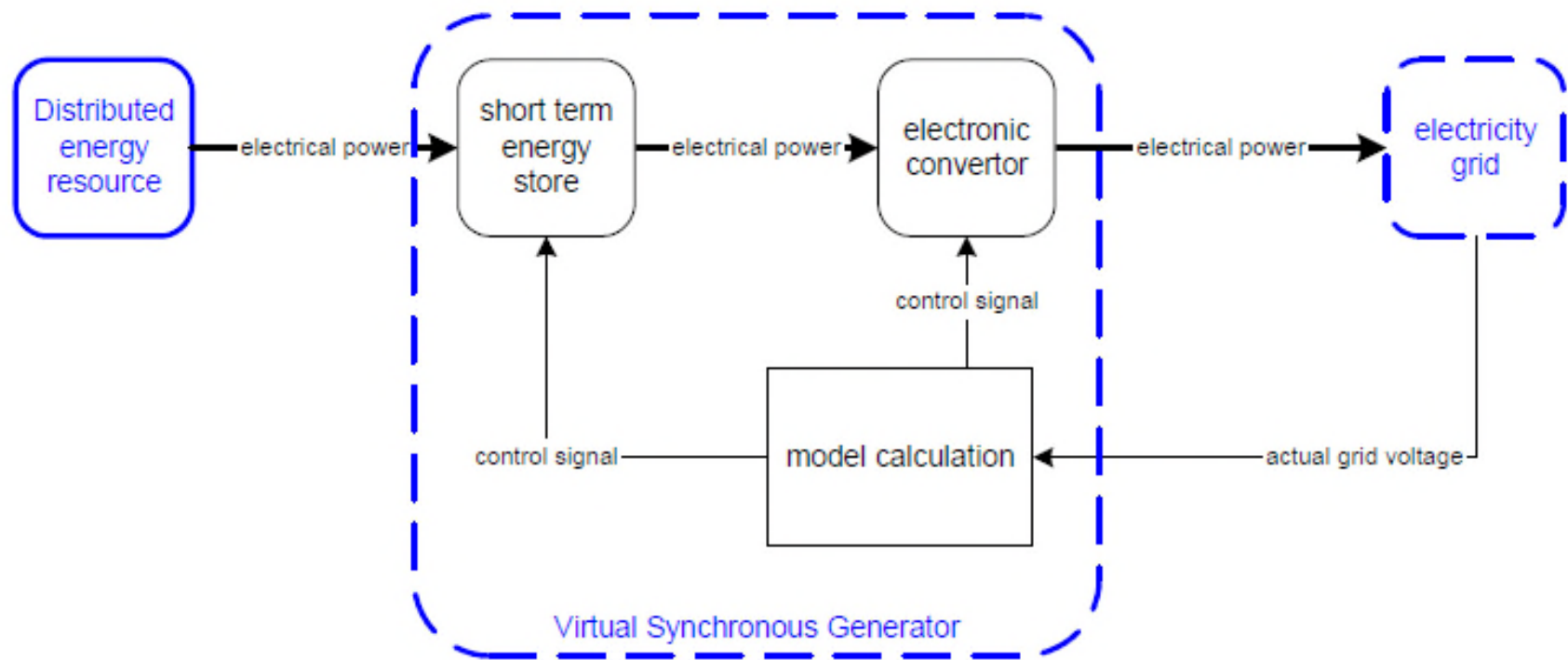


Part IV – Laboratory set-up

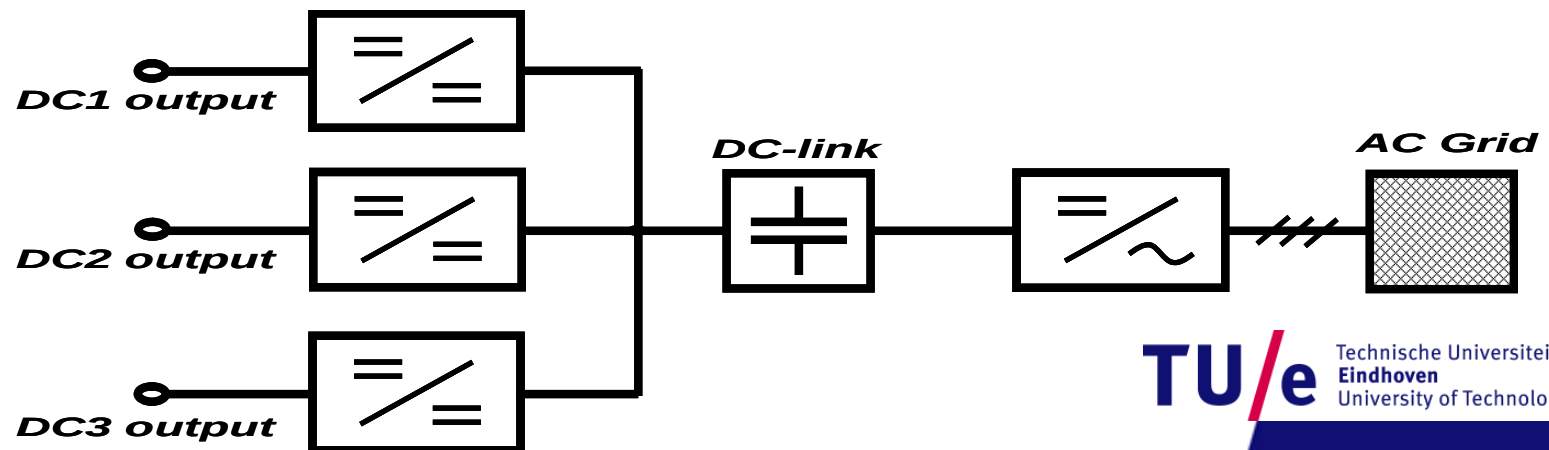
- Case Study – MAS interaction: Active power flow through inverters



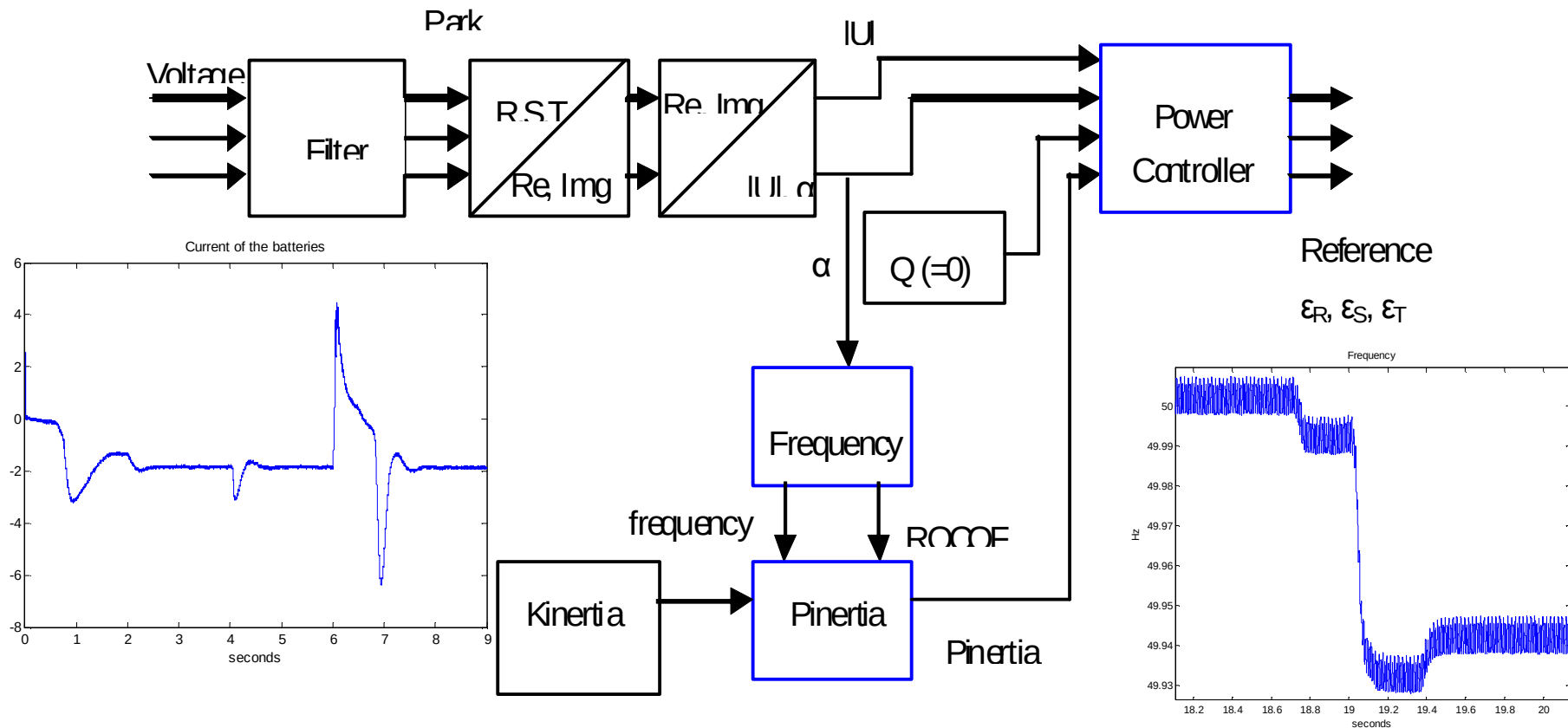
Other Examples: Virtual Inertia



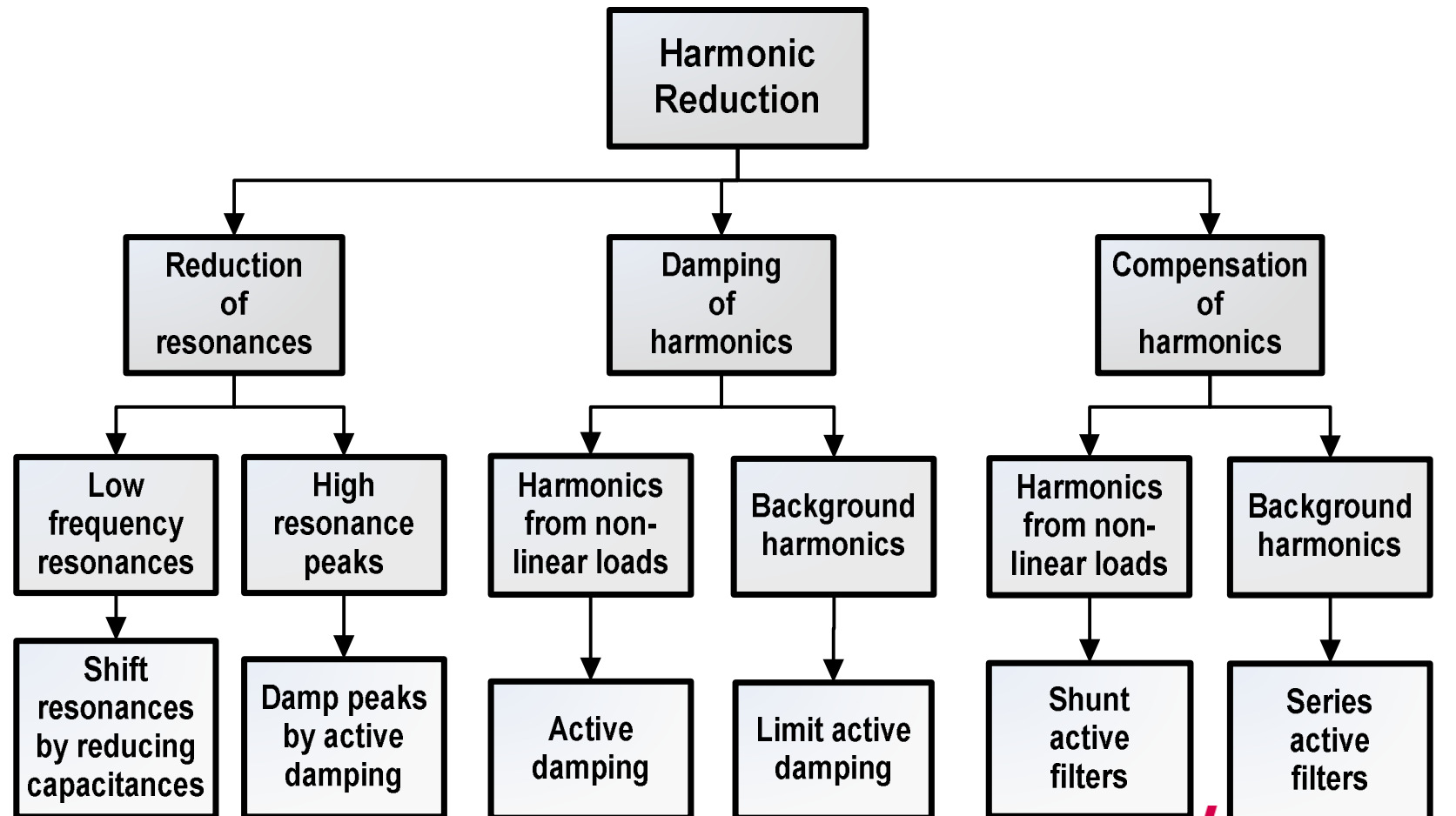
Other Examples: Virtual Inertia



Other Examples: Virtual Inertia



Other Examples: Power Quality Intelligent Inverters

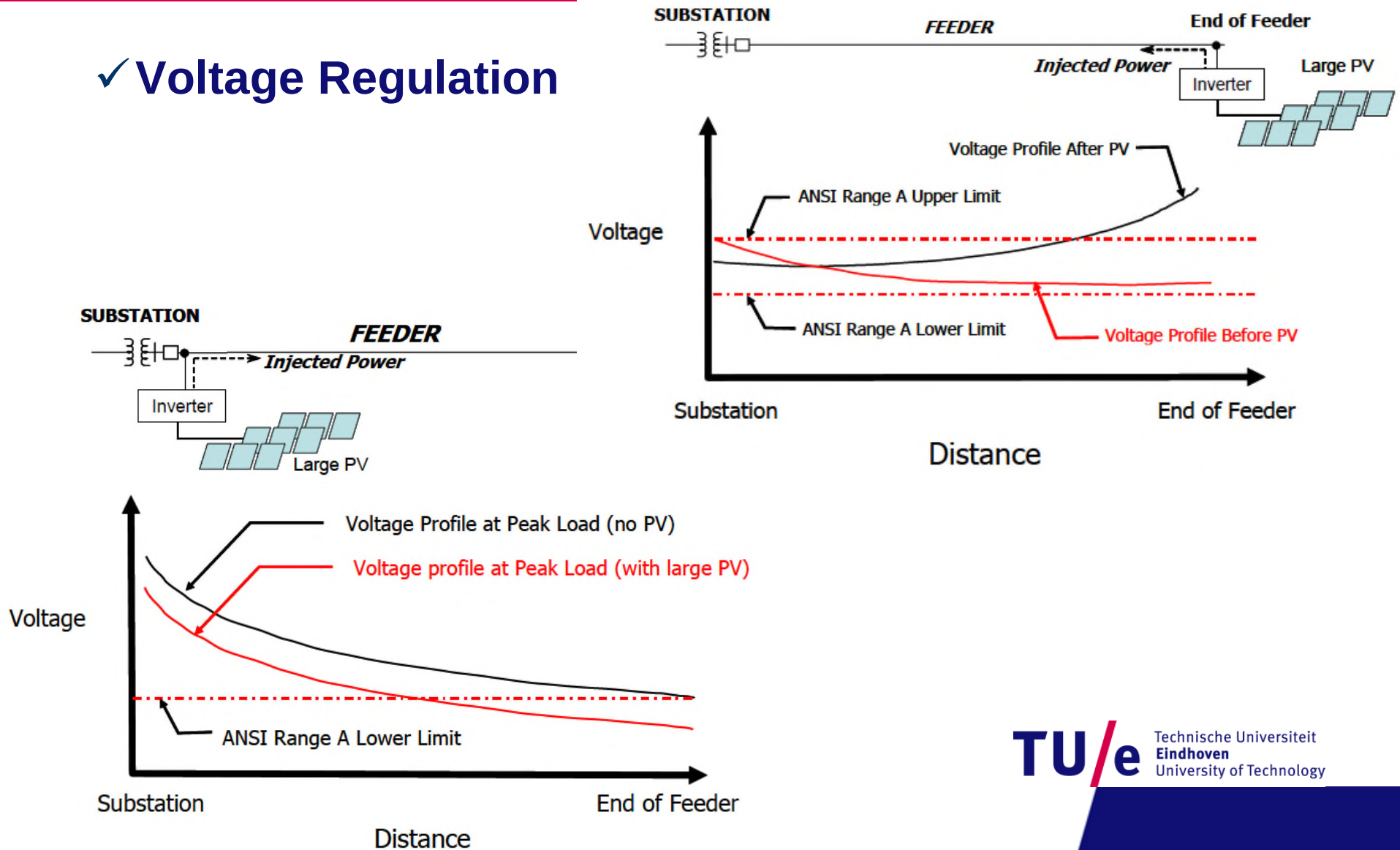


The Main Technical Issues affected by MG-DG-DER-RES (Smart Grids)

- ✓ **The majority of implications are related to:**
 - ✓ **Active and reactive energy flows paradigm;**
This is a new issue and the problems that occur have old solutions, generally timing the tripping.
 - ✓ **DG interconnections and Islanding;**
Plug-and-play and peer-to-peer.

The Main Technical Issues affected by MG-DG-DER-RES (Smart Grids)

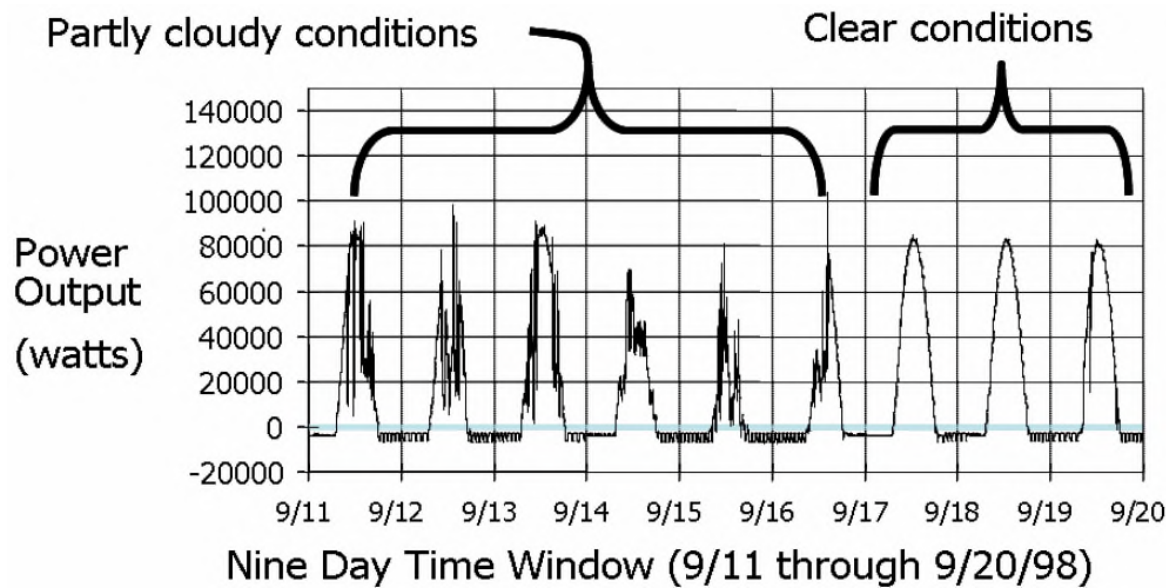
✓ Voltage Regulation



The Main Technical Issues affected by MG-DG-DER-RES (Smart Grids)

✓ Voltage Regulation

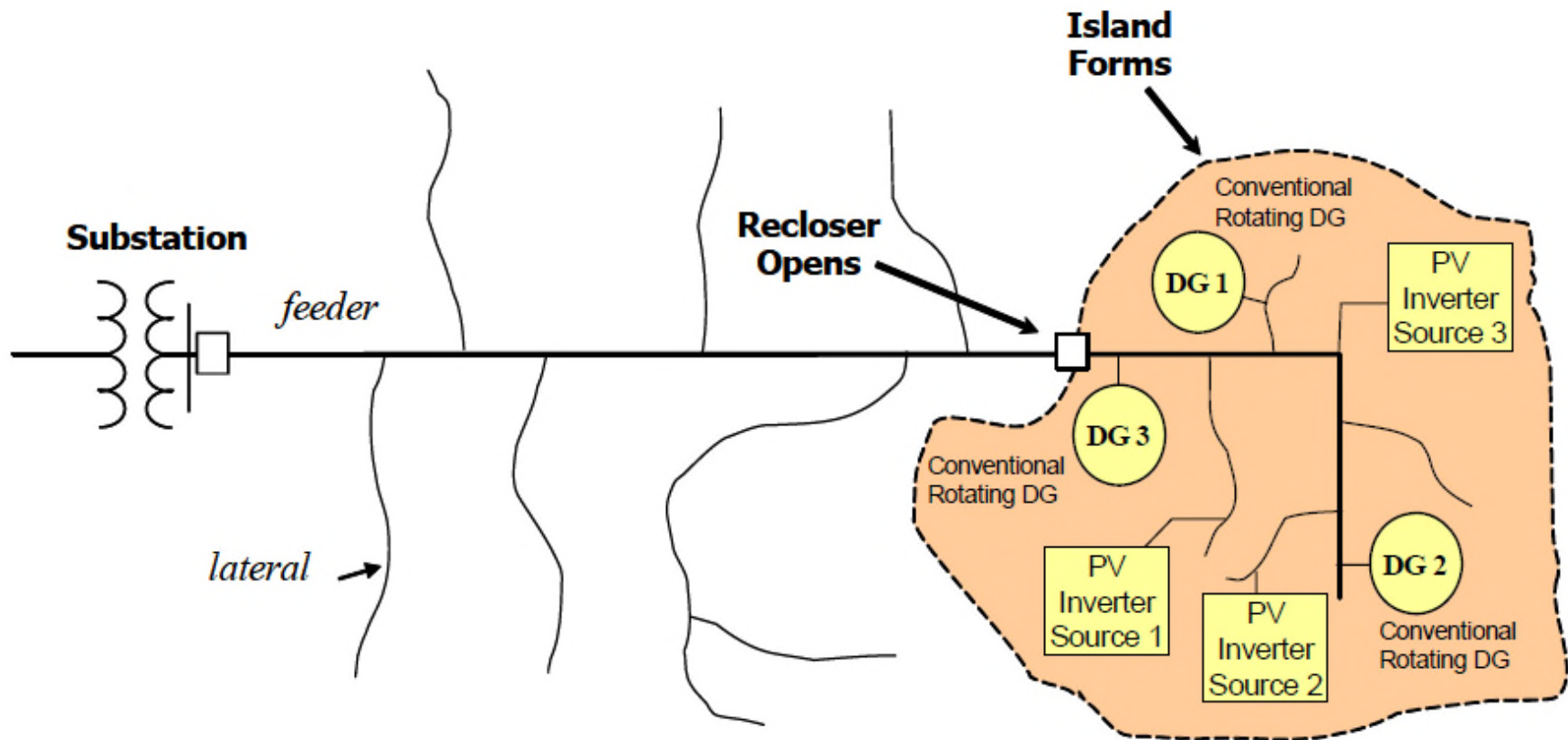
- ✓ Distribution-connected PV and wind energy sources in particular can fluctuate considerably and, with high penetration, can lead to noticeable problems, such as the ramp up or down caused by moving clouds.



PV power fluctuations at a 100-kW PV site near Albany, New York

The Main Technical Issues affected by MG-DG-DER-RES (Smart Grids)

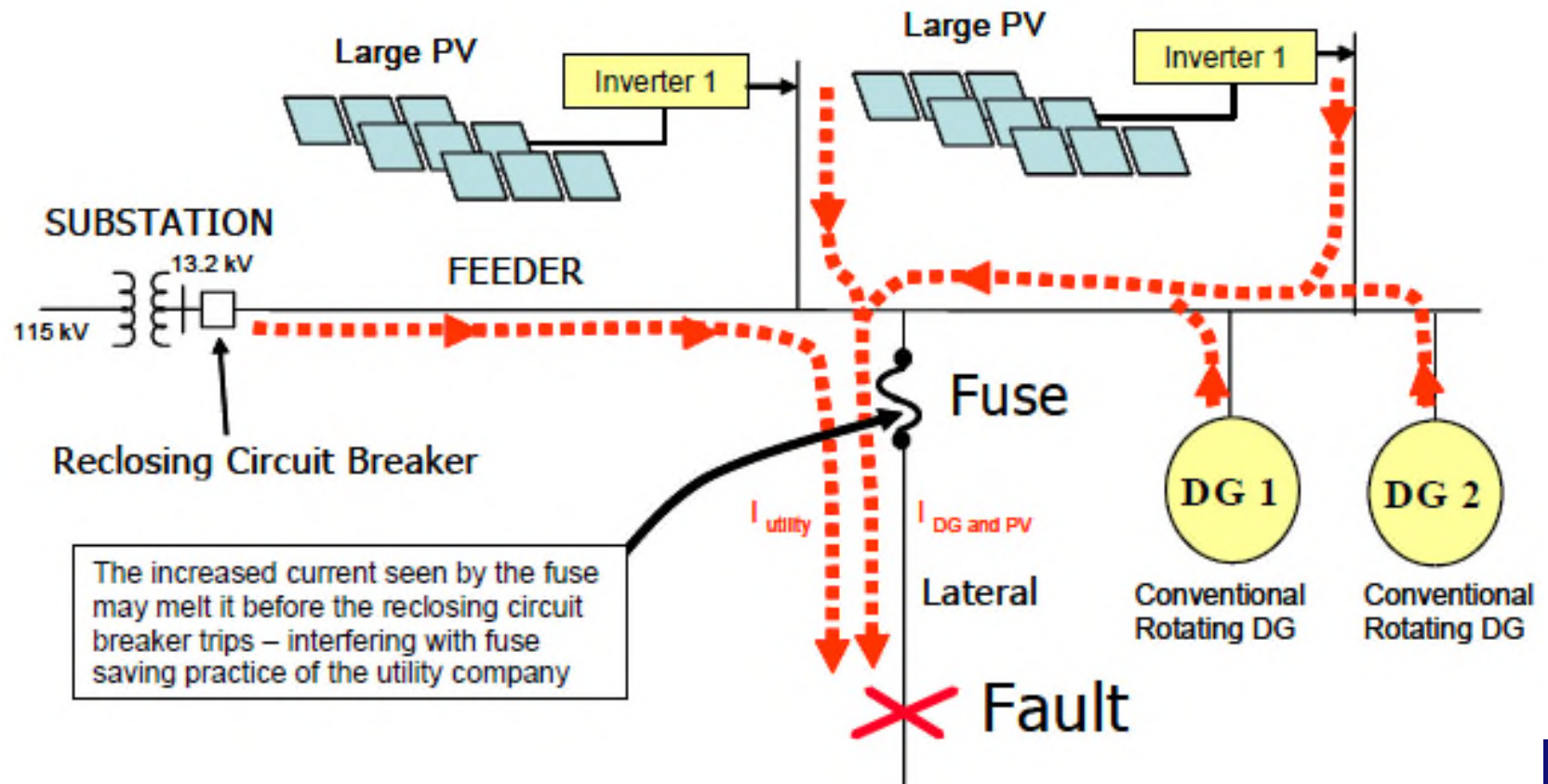
- ✓ Island
 - ✓ Intentional;
 - ✓ Unintentional.



The Main Technical Issues affected by MG-DG-DER-RES (Smart Grids)

✓ Protection

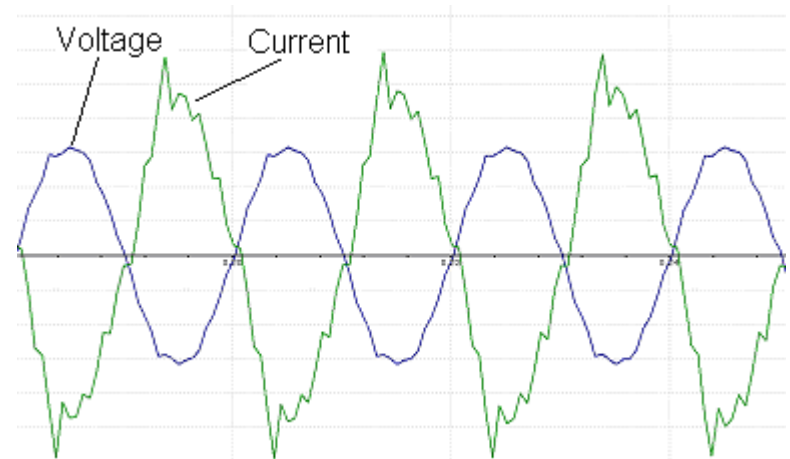
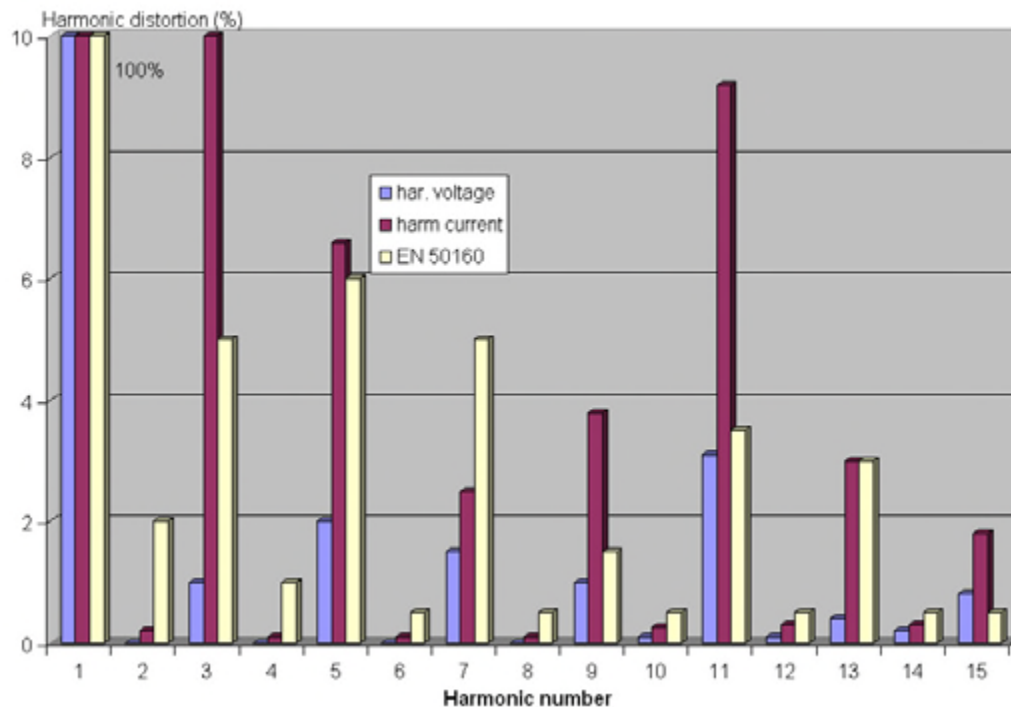
✓ Fuse Coordination (PV example)



The Main Technical Issues affected by MG-DG-DER-RES (Smart Grids)

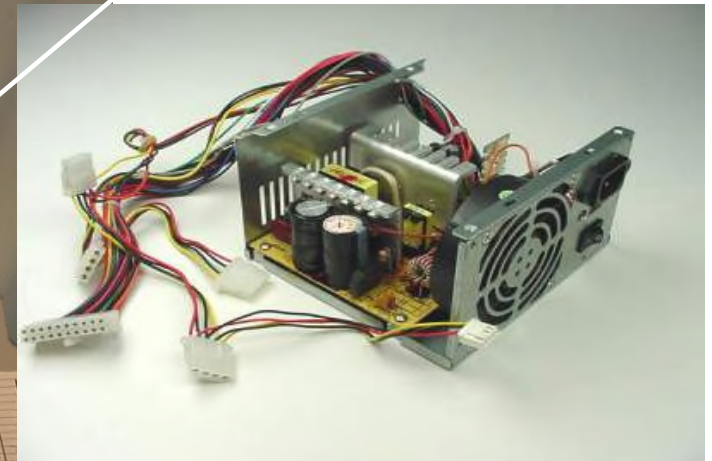
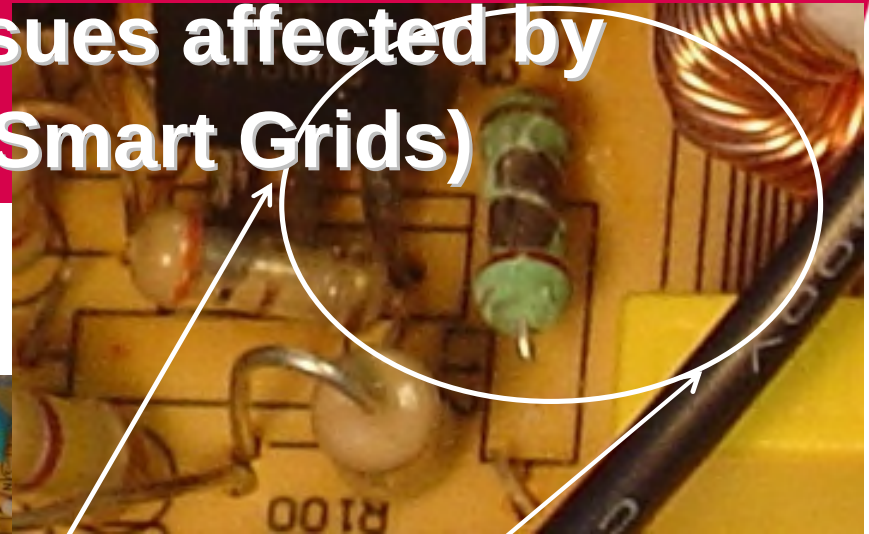
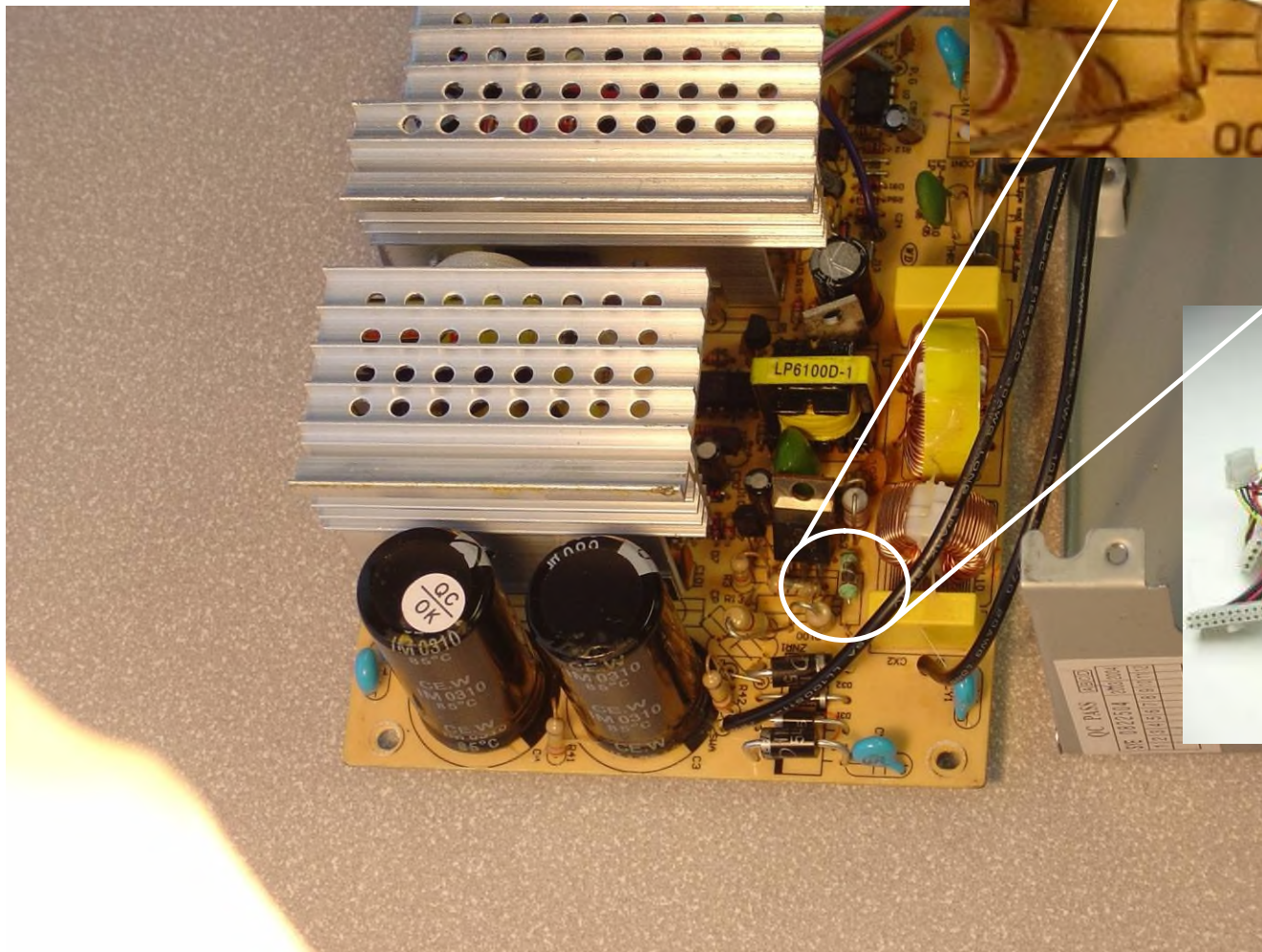
✓ Harmonics

To the high amount installed DG-inverters, the interaction between inverters harmonic currents and background harmonic voltage multiplied by the resonant behavior of the grid and loads harmonic distortion became significant

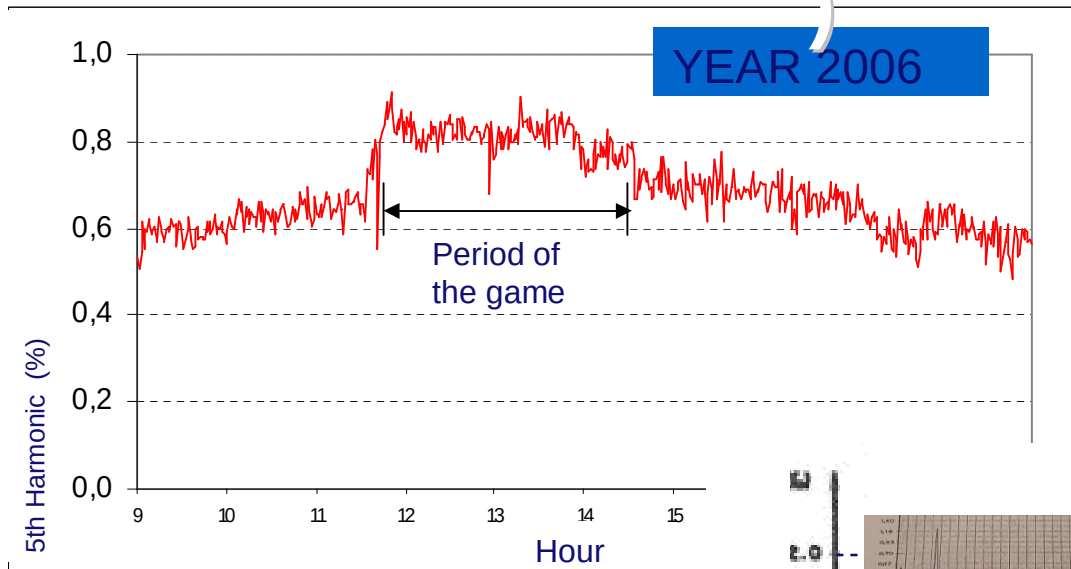


The Main Technical Issues affected by MG-DG-DER-RES (Smart Grids)

Waveform Impacts

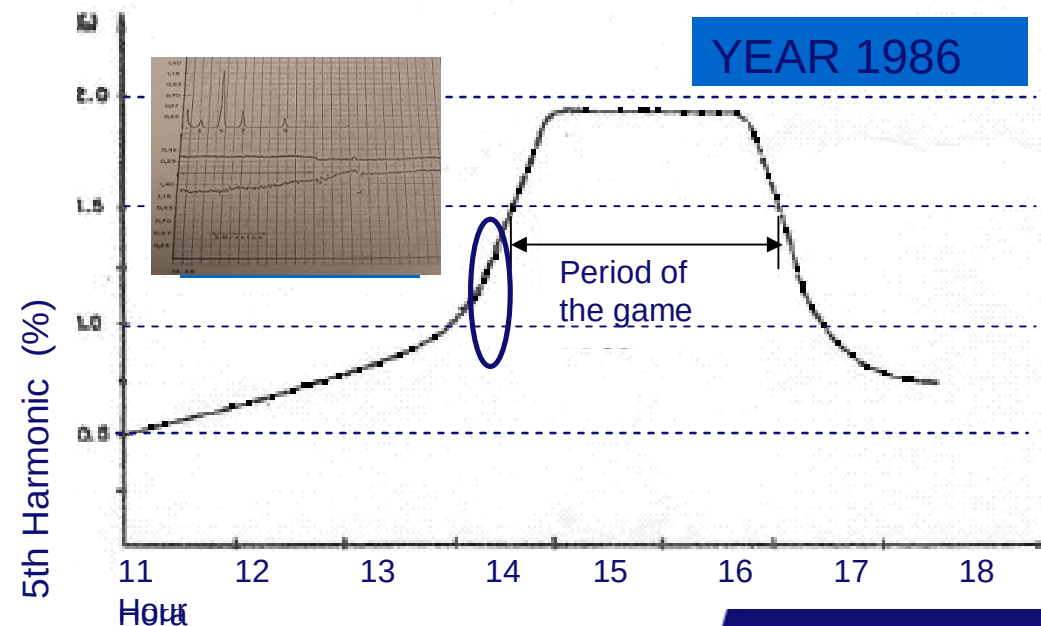


The Main Technical Issues affected by MG-DG-DER-RES (Smart Grids)



- Probably, the power supply of the modern TV receivers have a much smaller harmonic injection content.

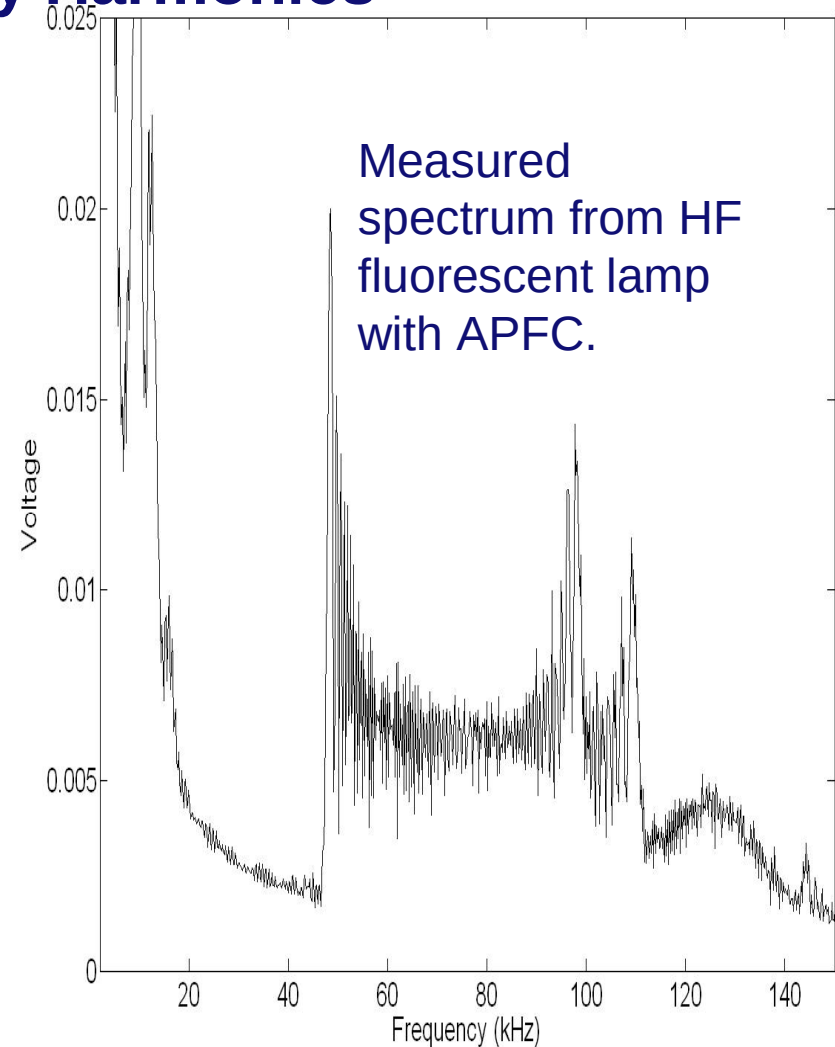
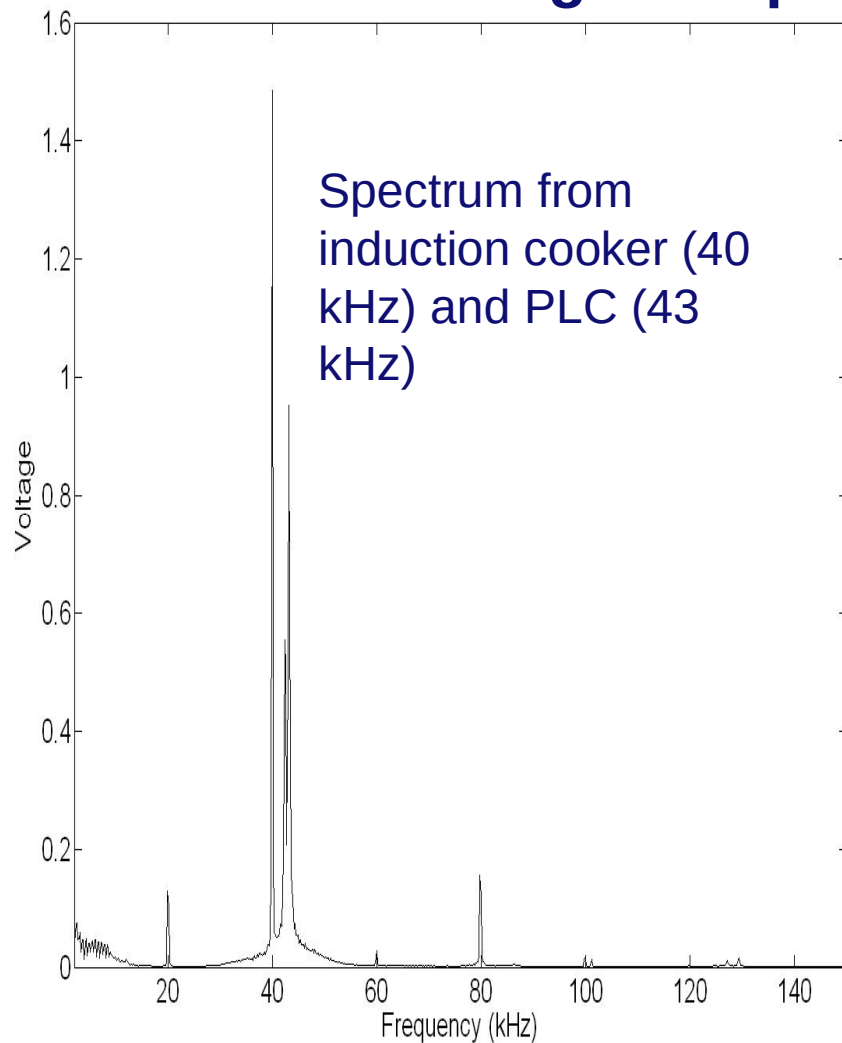
Measurement in Fortaleza 230 kV During the World Cup of 1986 and 2006



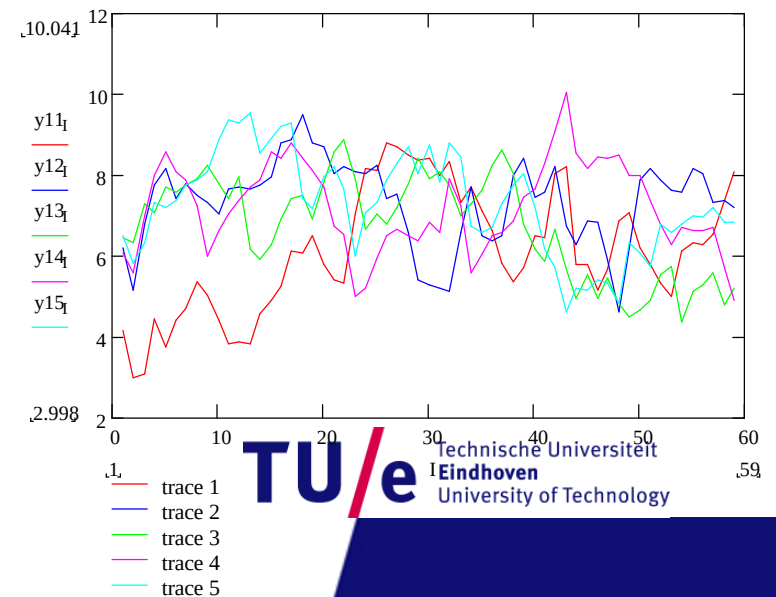
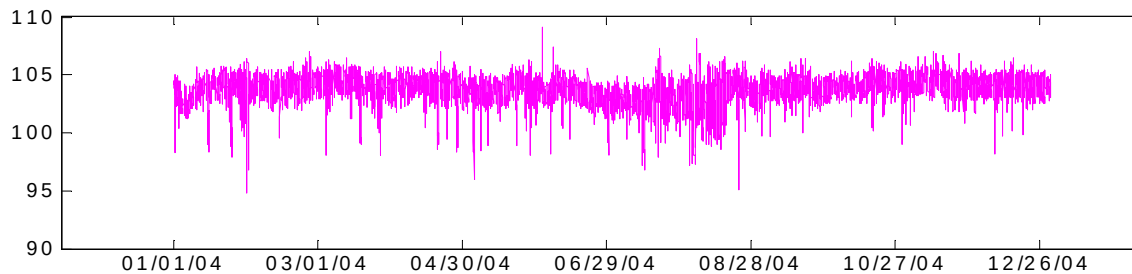
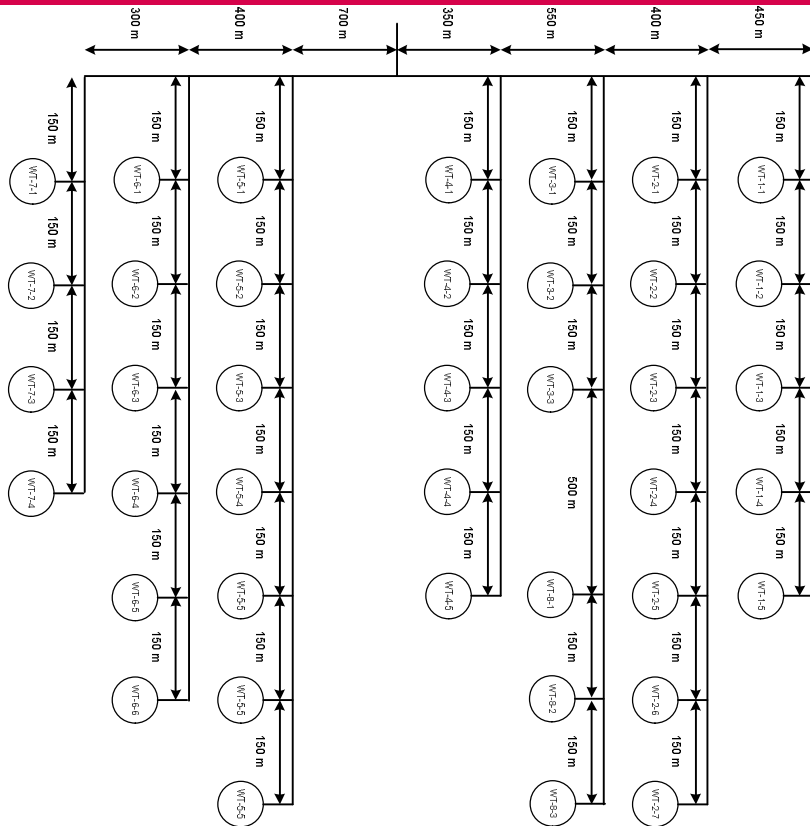
- The system impedance (at 5th harmonic frequencies) at the Fortaleza substation is lower now than it was 20 year ago.

The Main Technical Issues affected by MG-DG-DER-RES (Smart Grids)

High Frequency Harmonics

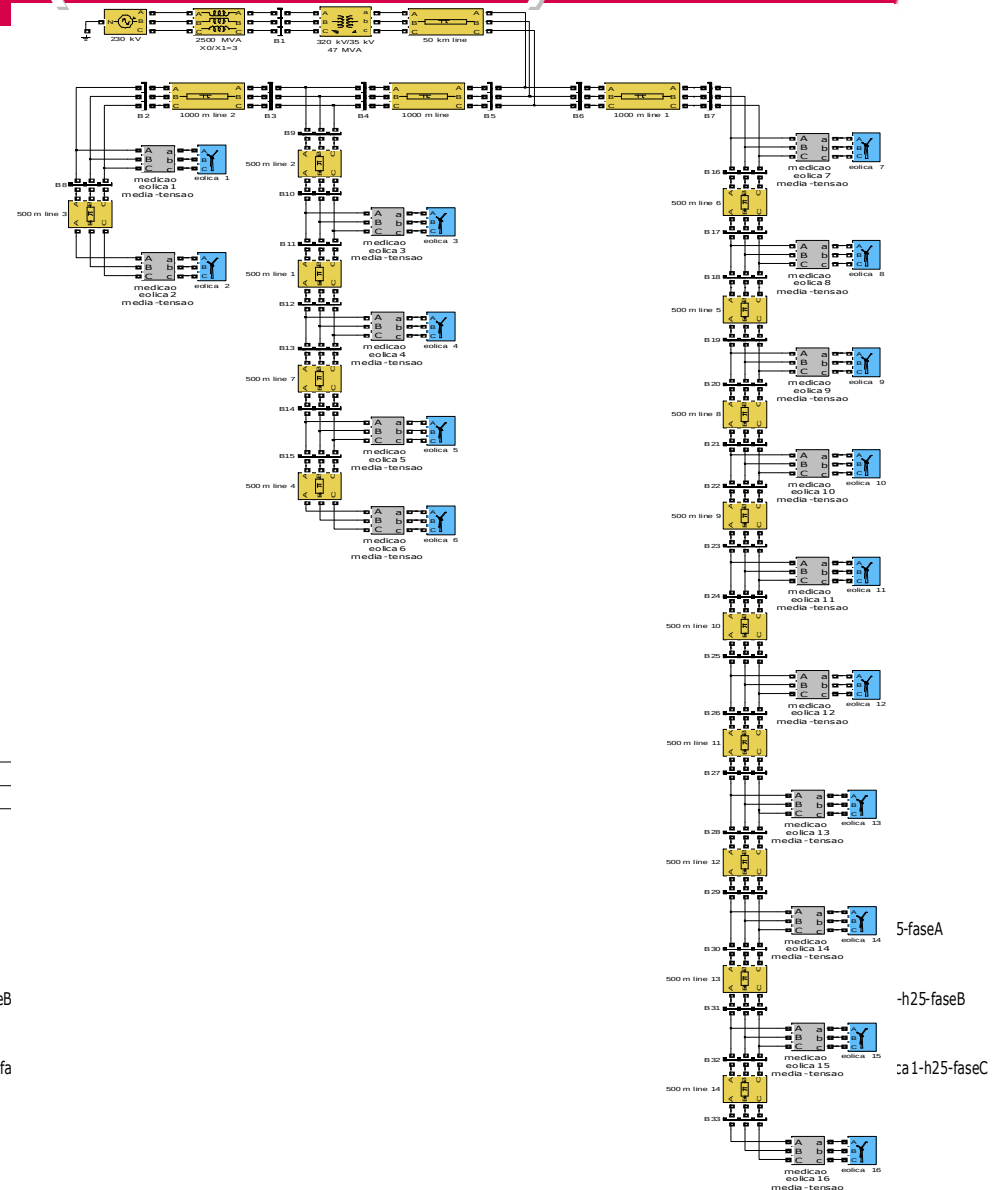
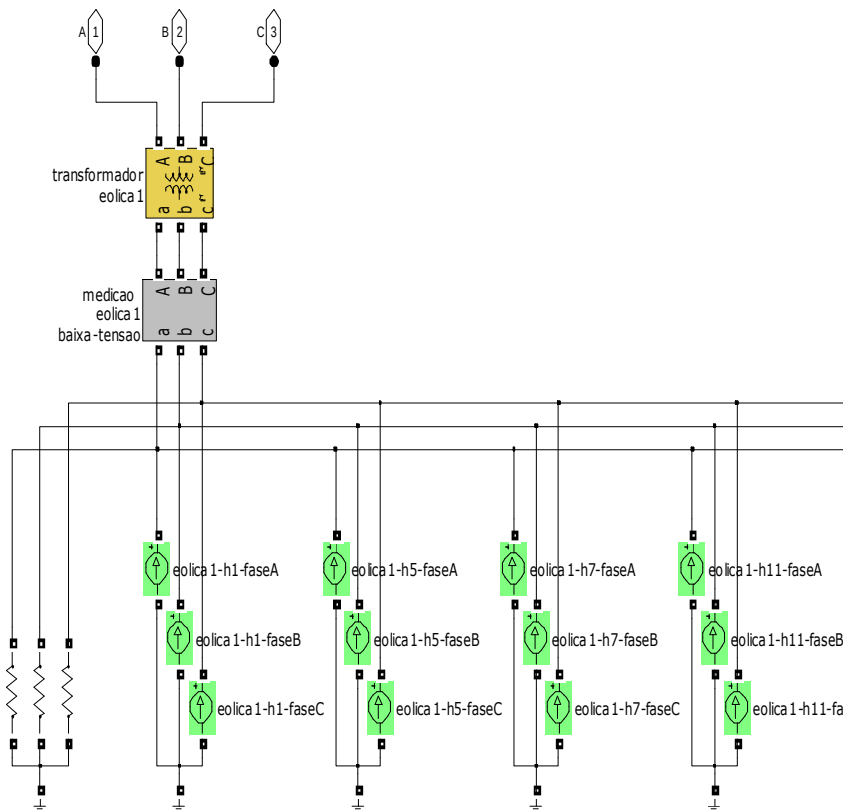


The Main Technical Issues affected by MG-DG-DER-RES (Smart Grids)



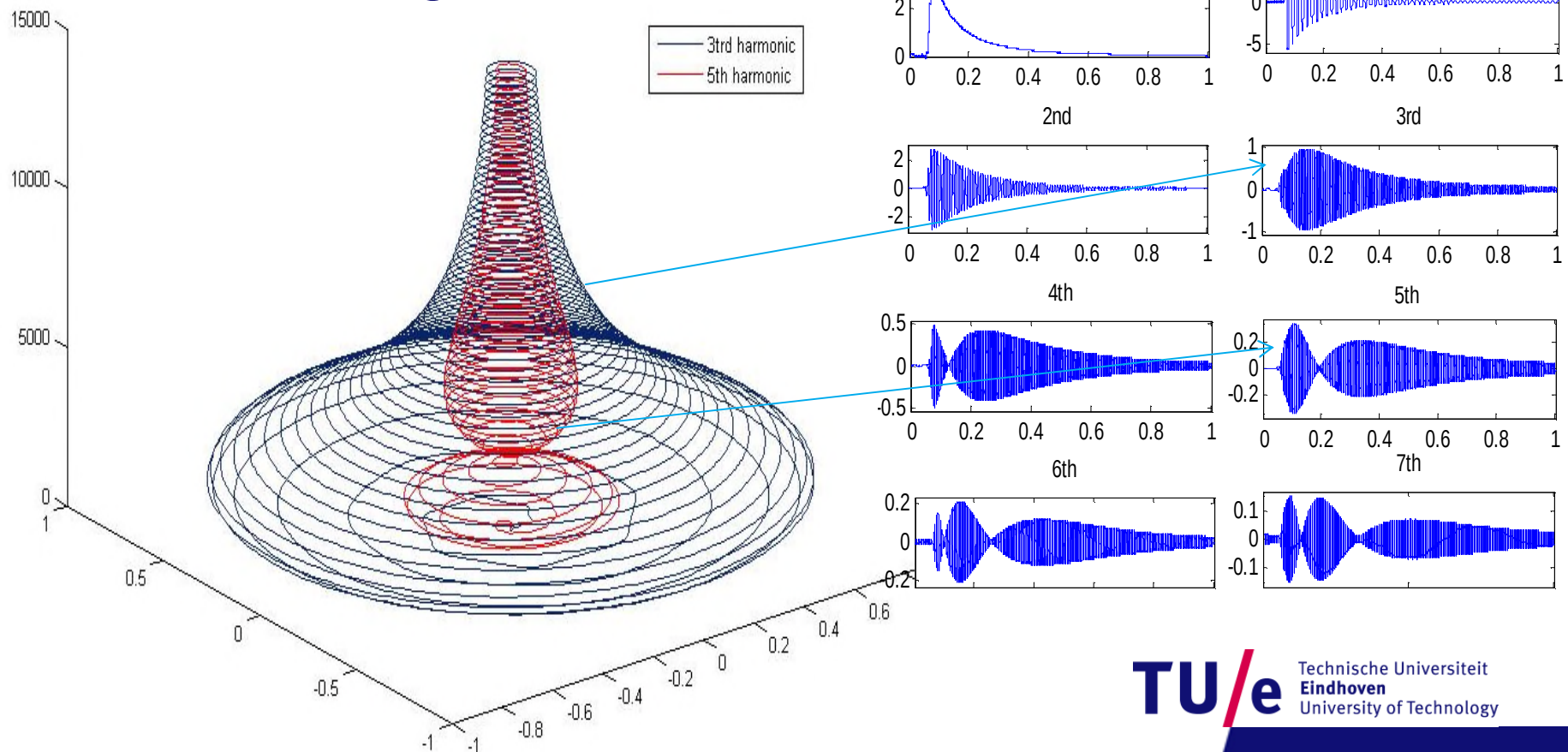
The Main Technical Issues affected by MG-DG-DER-RES (Smart Grids)

Aggregation of New Non-Linear Sources



The Main Technical Issues affected by MG-DG-DER-RES (Smart Grids)

✓ Time-Varying Harmonics: New Paradigm



The Main Technical Issues affected by MG-DG-DER-RES (Smart Grids)

- ✓ **Others:**
 - ✓ **Stability (voltage and frequency);**
 - ✓ **Transients;**
 - ✓ **Unbalance;**
 - ✓ **Resonance;**
 - ✓ **Measurement;**
 - ✓ **Faults;**
 - ✓ **Short circuits levels;**
 - ✓ **Sustained Interruption.**

What will be the Implications on Signal Measurement

In the smart grid, reliable and online information becomes the key factor for reliable delivery of power from the generation units to the end-users.

What will be the Implications on Signal Measurement

- ✓ **Why smart metering?**
 - ✓ **User Profile, Energy Efficiency Measurement, Benchmarking, Management, Energy cost allocation and analysis, Building Control, Demand Control, Automation, Preventive Maintenance, Power Quality Measurement, Fault Analysis, Check Meter, Carbon emission reduction.**

A smart grid requires advanced monitoring and analysis that can anticipate contingencies and prevent local disturbances by intelligent monitoring.

What will be the Implications on Signal Measurement

- ✓ **Recent needs:**
 - ✓ Accuracy (Ex: to control power flow) ;
 - ✓ Synchronized measurements (Ex: synchrophasors);
 - ✓ Measurement in many nodes of power networks;
 - ✓ Measurement information meet the standards that recommend a proper well-established uncertainty;
- ✓ **New issues:**
 - ✓ Reliability of electronic meters;
 - ✓ Power quality/EMC;
 - ✓ Power line communication;
 - ✓ On-site testing and quality management;
 - ✓ Software security;
 - ✓ Small scale production of electricity.

Opportunities for Research and Development

From an overall system performance perspective, the efficiency of generation and the transmission and distribution systems has improved slightly, while capacity factors, system reliability, and power quality has remained mainly flat.

Opportunities for Research and Development

- **DG, T&D automation, smart meters**
- **Real-Time data sharing, distributed resources interconnection standards, advanced measurement systems**
- **Load participation, micro grids, plug-in EV, etc.**
- **Cyber security, open-architecture / standards**

Opportunities for Research and Development

- ✓ **Development**
 - ✓ Substantially increase the use of existing production assets;
 - ✓ Readily accommodate new generation, transmission, distribution, and consumer technologies;
 - ✓ Actively identify and extract energy efficiency throughout the system;
 - ✓ Address growing complexity of efficient system operations through highly distributed automation;
 - ✓ Deliver appropriate levels of power quality, and reliability to different end-use needs;
 - ✓ Improving the security posture of the system.

Opportunities for Research and Development

- ✓ **Proposed Areas of Research on General**
 - ✓ Understand the interdependencies of electric, communications, and other infrastructures, as well as their reaction and stability to system disturbances;
 - ✓ Study the behavior of end-users reaction to and acceptance of smart grid functions;
 - ✓ Analyze the impact on generation, transmission, and distribution capacity from DER in demand response markets, including prices that reflect system operating constraints;

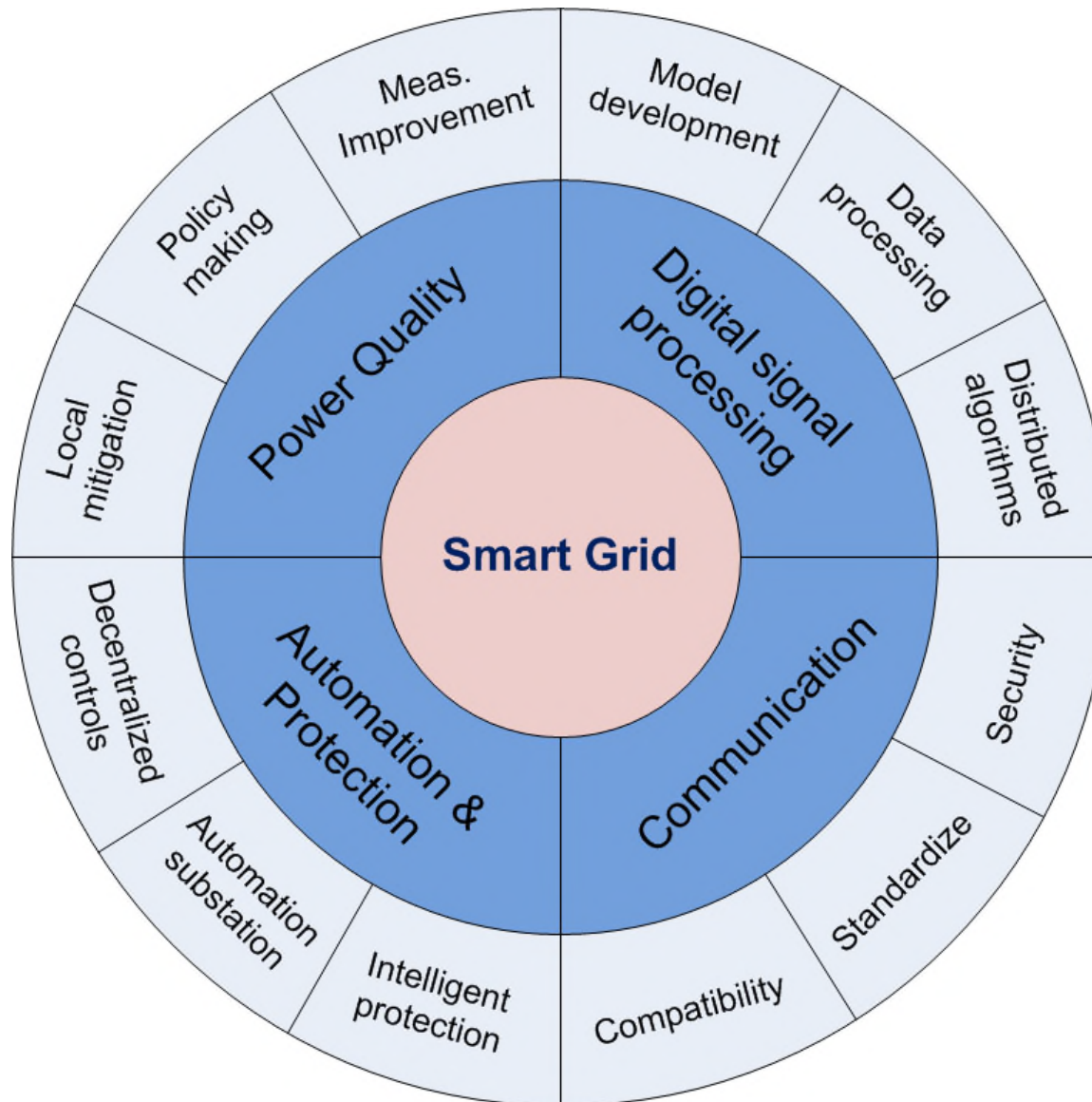
Opportunities for Research and Development

- ✓ **Proposed Areas of Research on General**
 - ✓ Estimate the ability of smart grid resources to enhance energy efficiency including awareness, diagnostics, and validation of energy efficiency programs;
 - ✓ Estimate the societal benefits of smart grid and considerations for cost/benefit allocation by policymakers;
 - ✓ Standardize formats for smart grid device and system description and exchange;
 - ✓ Integrate smart grid engineering models with service provider enterprise systems, e.g., work order, outage management, and AM/FM/GIS systems;

Opportunities for Research and Development

- ✓ **Proposed Areas of Research on General**
 - ✓ Research mixed direct and alternating current electric distribution technologies;
 - ✓ Advance power electronics technology for electricity transformation to manage storage, charging stations, voltage control, and reactive compensation;
 - ✓ Verify performance of smart grid technologies, including control methods and interoperability;
 - ✓ Provide test processes and facilities to support product development;
 - ✓ Develop requirements and tests to advance interoperability and ease integration, maintenance, and upgrade;

Opportunities for Research and Development



Opportunities for Research and Development

Challenges

Research and Development

DG Integration (Catalyzer)

- Compatibility with Transmission Requirements and Load Sensitivity
- Levels of Penetration per Technology
- Integration of Communications and Computer Control

Systems Issues

- State Estimation for Contingency Analysis
- Modeling and Simulation: Graph Visualization e Software Integration
- Probabilistic Aspects and Novel Techniques

Technology Development

Politics and Economics: PSC of Maryland Decision on Smart Grid Proposal

ORDER NO. 83410

IN THE MATTER OF THE APPLICATION	*	BEFORE THE
OF BALTIMORE GAS AND ELECTRIC	*	PUBLIC SERVICE COMMISSION
COMPANY FOR AUTHORIZATION	*	OF MARYLAND
TO DEPLOY A SMART GRID INITIATIVE	*	
AND TO ESTABLISH A SURCHARGE FOR	*	
THE RECOVERY OF COST	-	CASE NO. 9208

In this Order, we deny Baltimore Gas and Electric Company's ("BGE" or the "Company") Application for Authorization to Deploy a Smart Grid Initiative and to Establish a Surcharge Mechanism for the Recovery of Costs (the "Proposal"). Although we share BGE's (and others') hopes, and even enthusiasm, for the long-run potential and importance of the infrastructure upgrades known colloquially as the "smart grid," we find the business case for *this* Proposal untenable. The Proposal asks BGE's ratepayers to

Politics and Economics: PSC of Maryland Decision on Smart Grid Proposal

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THE RECOVERY OF COST

*
*
*
*

BEFORE THE
PUBLIC SERVICE COMMISSION
OF MARYLAND

CASE NO. 9208

I. Introduction and Executive Summary

In this Order, we deny Baltimore Gas and Electric Company's ("BGE" or the "Company") Application for Authorization to Deploy a Smart Grid Initiative and to Establish a Surcharge Mechanism for the Recovery of Costs (the "Proposal"). Although we share BGE's (and others') hopes, and even enthusiasm, for the long-run potential and importance of the infrastructure upgrades known colloquially as the "smart grid," we find the business case for *this* Proposal untenable. The Proposal asks BGE's ratepayers to take significant financial and technological risks and adapt to categorical changes in rate design, all in exchange for savings that are largely indirect, highly contingent and a long way off. We are not persuaded that this bargain is cost-effective or serves the public interest, at least not in its current form. But we invite BGE to revisit its Proposal in light

Politics and Economics: PSC of Maryland Decision on Smart Grid Proposal

Supply-side benefits relies upon numerous key assumptions, including, among others:

- (1) customers will continue to receive a PTR rebate equal to the initial estimate of \$1.25/kWh;
- (2) 70% of non-PeakRewards residential customers and 50% of non-PeakRewards small commercial customers will participate in shifting their energy use during declared critical peak periods;
- (3) those non-PeakRewards residential customers who do participate will reduce their peak load by an average of 0.49 kW and those non-PeakRewards small commercial customers who do participate will reduce their peak load by an average of 0.60 kW; E value of \$176 per MW-day.¹⁰²

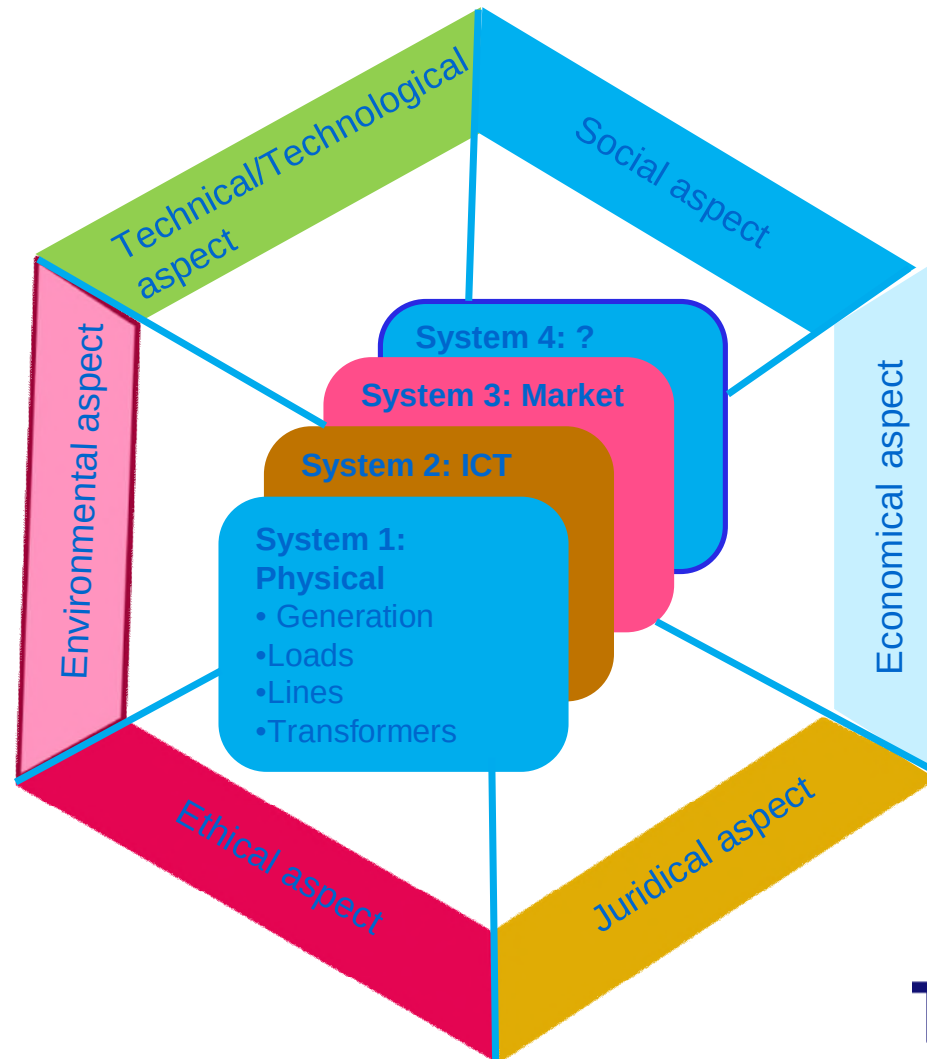
Politics and Economics: PSC of Maryland Decision on Smart Grid Proposal

- (4) 90% of PeakRewards residential customers and 50% of PeakRewards small commercial customers will participate in shifting their energy use during declared critical peak periods;
- (5) those PeakRewards residential customers who do participate will reduce their peak load by an average of 0.10 kW and those PeakRewards small commercial customers who do participate will reduce their peak load by an average of 0.12 kW, both of these in addition to their PeakRewards peak load reduction;
- (6) R-SEP and customer access to certain data through the web portal will reduce overall consumption by 1%; and 24
- (7) capacity prices subsequent to the 2012-13 delivery year will, on average, equal the 2012-13 SWMAAC NetCONE value of \$176 per MW-day.¹⁰²

Philosophy to Cope with Complexity

Smart-Grid	Fundament al Functions	Highest Subject Functions	Qualifying Functions	Working Functions
Electrical Generation	Physical	Social Economical	Social Economical	Physical
Distribution	Physical	Social Economical	Social Economical	Physical
Customers Demands	Physical	Social		
Market	Economcial	Social Economical		
ICT				

Philosophy to Cope with Complexity



Conclusion

- Many of the standards we need are already there
- There are different needs in different environments
 - Define new applications and procedures
 - Agree on common information models
 - Adopt, evolve existing technologies and protocols
 - Develop new technologies and protocols
 - Apply systems engineering discipline
- Each of these tasks comes with a cost
- Standards provide the most benefit when implemented frequently and pervasively
- Pay attention to the business case
- Specify the use of standards in RFP's
- Synchronize with the NIST roadmap

Conclusios

Electric Power and Energy Systems will continue to grow in complexity and importance as the electric sector operates within a truly free economy.

Utilities, customers, manufacturers, universities / research institutions will have to cooperate to establish a stable model for the power sector

Recent and Advanced Technologies and Techniques will create new challenges and opportunities

Universities and Research Institutions will have to adapt to face the new environment

An integrated Approach Is Essential to Guarantee Sustainability
Vision, Philosophy/Strategy and Integrated Initiative

Beyond Engineering Projects

A couple of years ago, when I was at grocery store in Grand Rapids, Michigan, examining some mango fruits, I did not know I was in for a surprise: the label on the mangos read “Sao Francisco Valley, Brazil.” My heart pounded faster with excitement ... this was the location of an irrigation project I had worked on its system studies for the substation expansion to include the irrigation load.

Finally, after over 25 years the connection of a power engineering project and a tropical fruit became very clear and I saw how electrical engineering plays an integral part on the wellbeing and sustainability of society – for smart living.

