



Distribution System Modeling Challenges for the Smart Grid

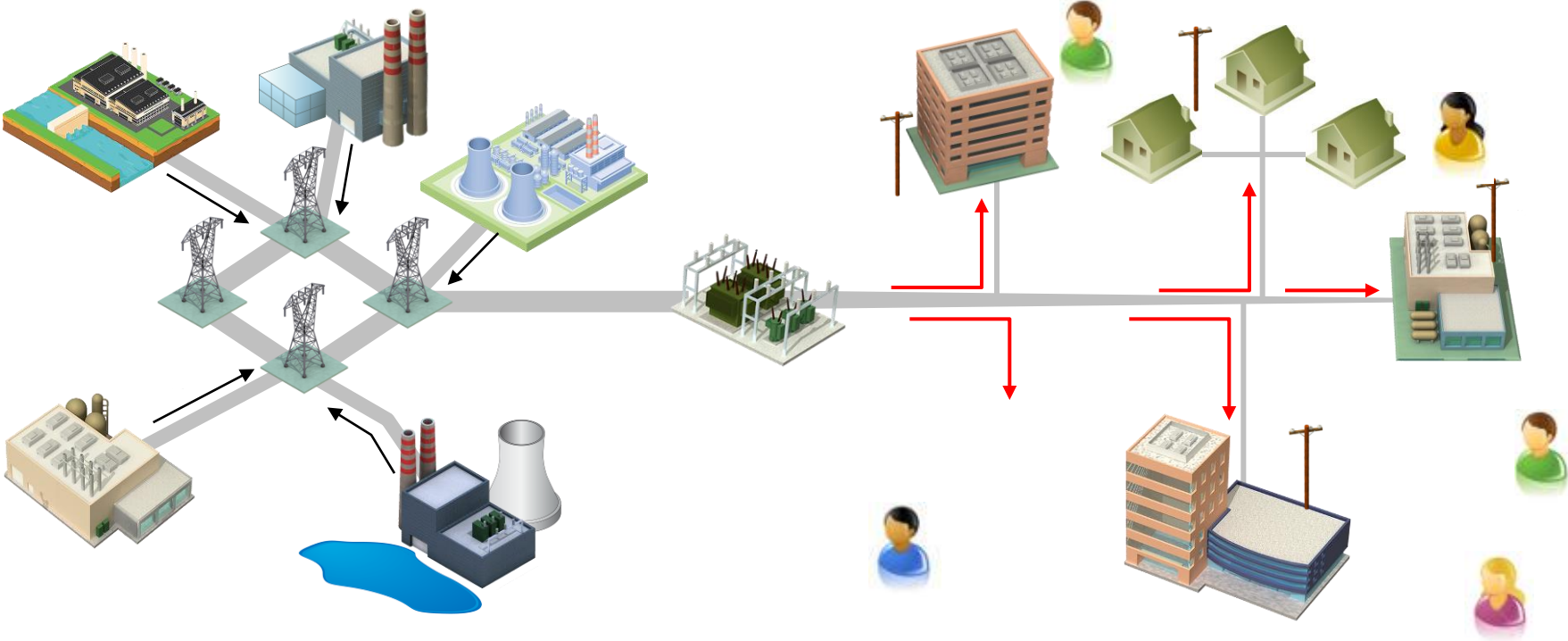
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Knoxville, TN
Nov 12, 2013

Distribution Systems and Micro-Grid Developments
8th Annual Pitt Electric Power Industry Conference

Distribution Planning Challenges for Grid of the Future

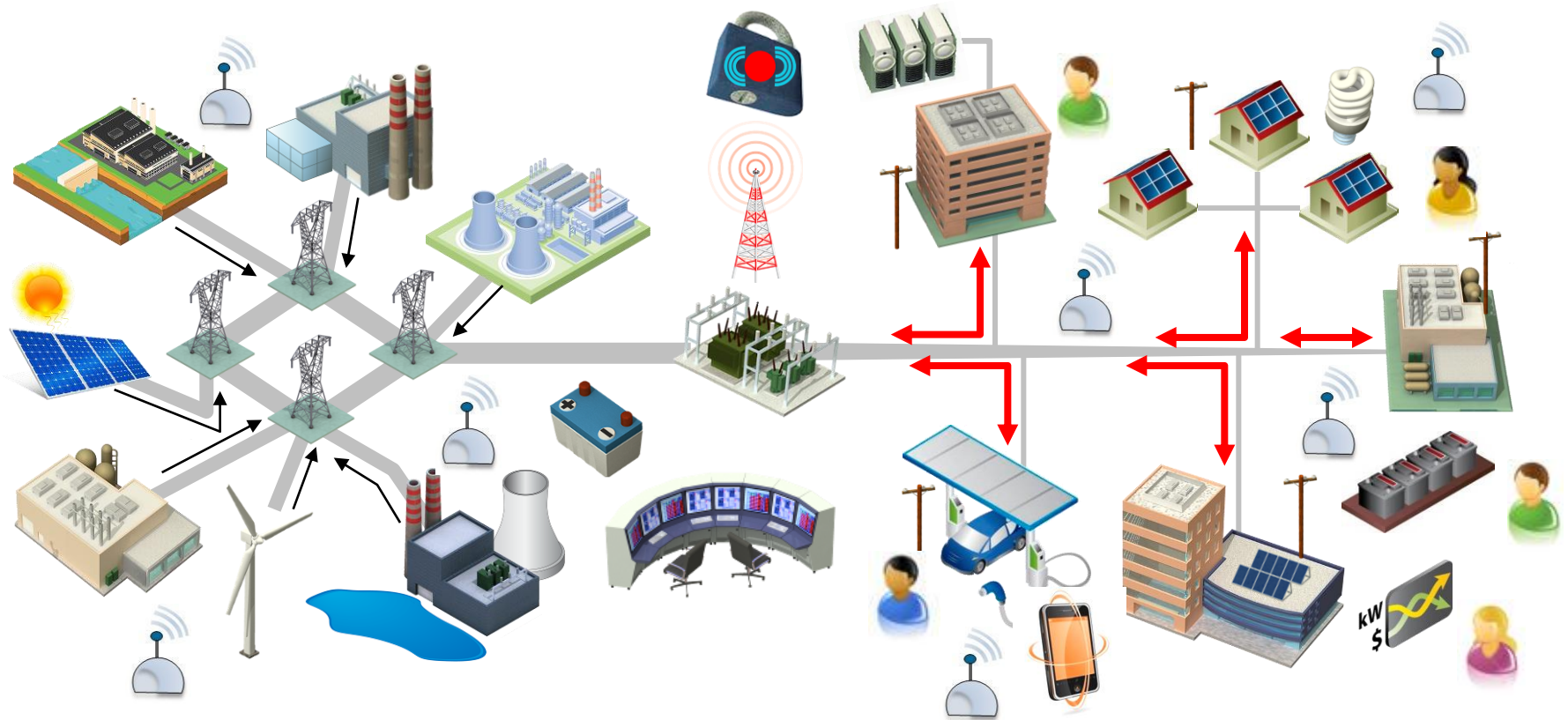
- The Grid of the Future will rely more on the Information and Communications Technology (**ICT**) infrastructure
- Utility distribution planners use Distribution System Analysis (DSA)
 - To design the *Power Delivery* infrastructure
 - They do not include the ICT system
- No integrated tools exist for Distribution Planning with ICT
- Interest in “Co-simulation” of power delivery and ICT is rapidly growing
 - An area ripe for research

Today's Power System



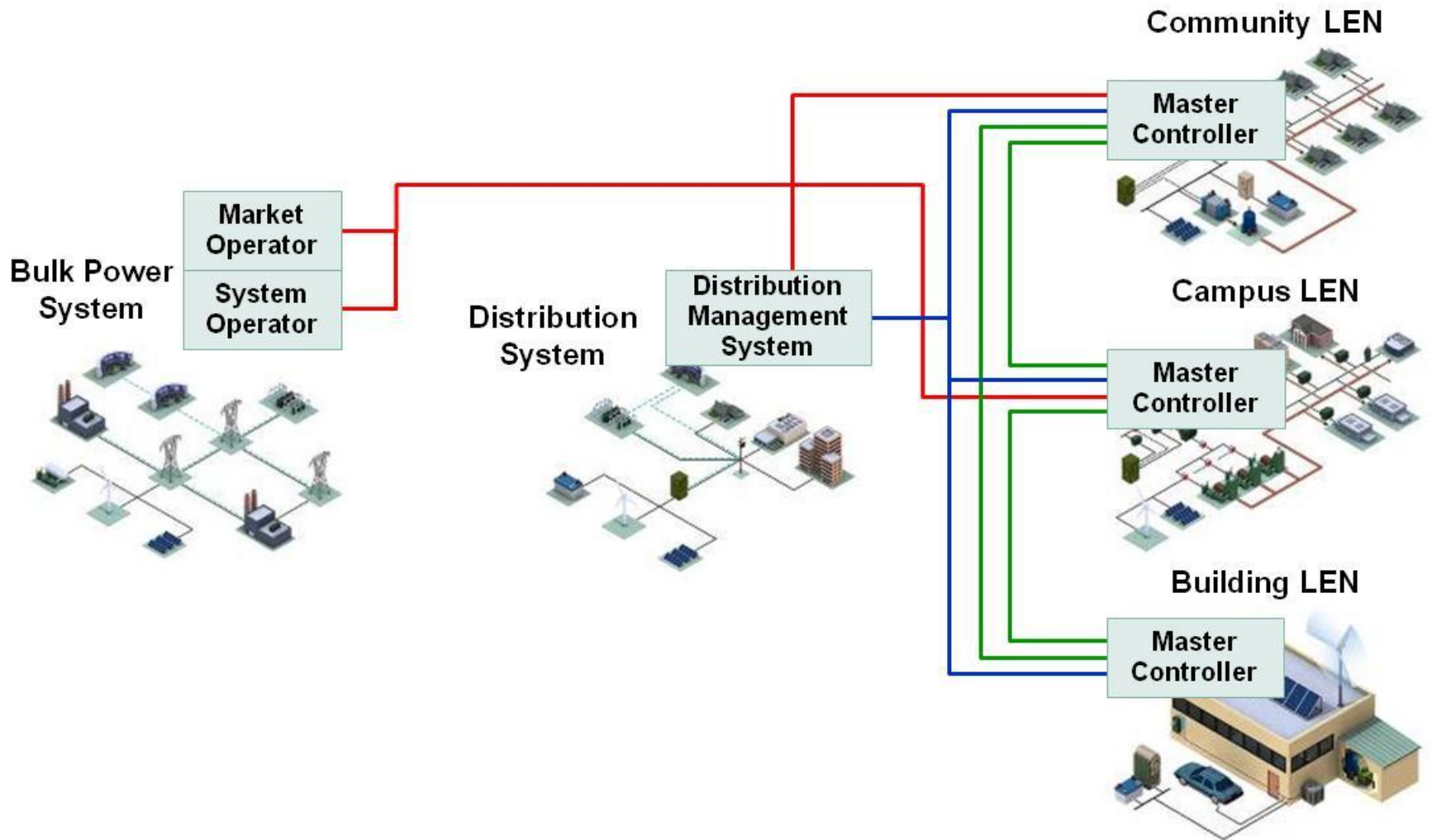
$$\begin{array}{ccccccc}
 \text{Base Load Generation} & + & \text{Load Following Generation} & +/\text{-} & \text{Bulk Energy Storage} & = & \text{Customer Demand} - \text{Interruptible Load DR}
 \end{array}$$

Tomorrow's Power System

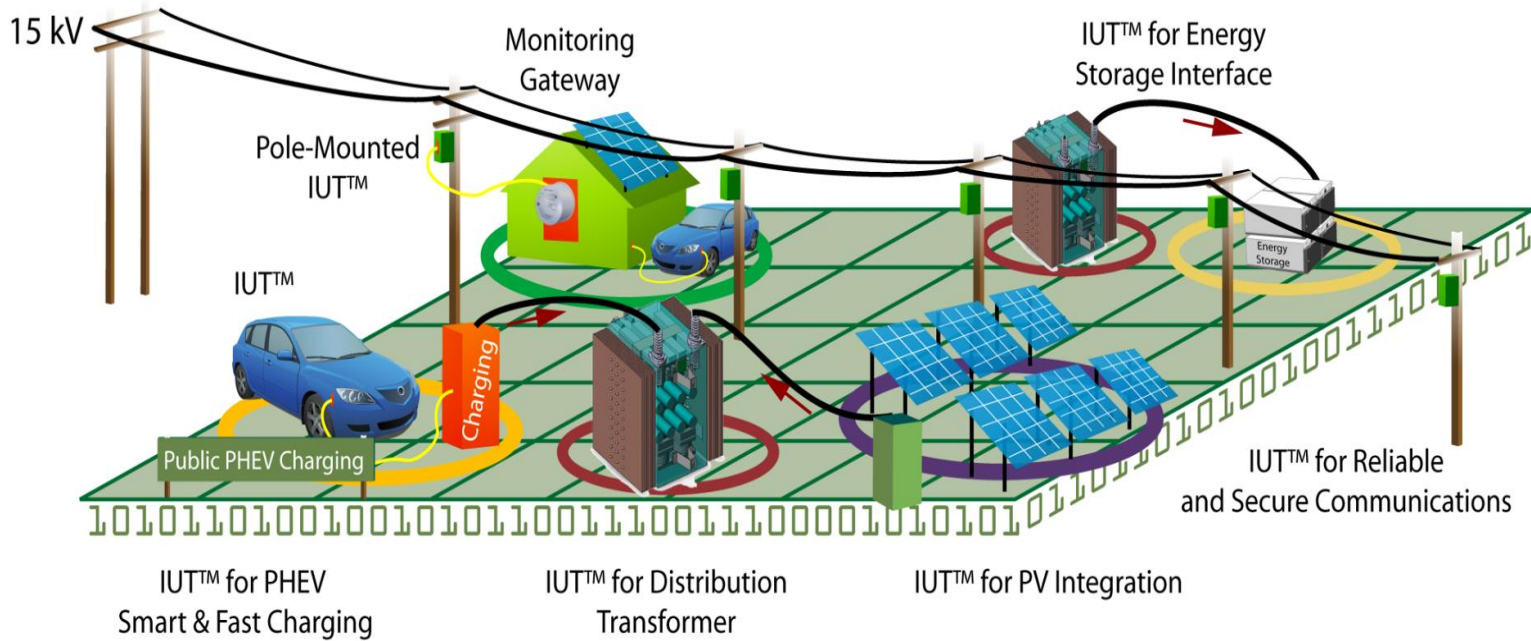
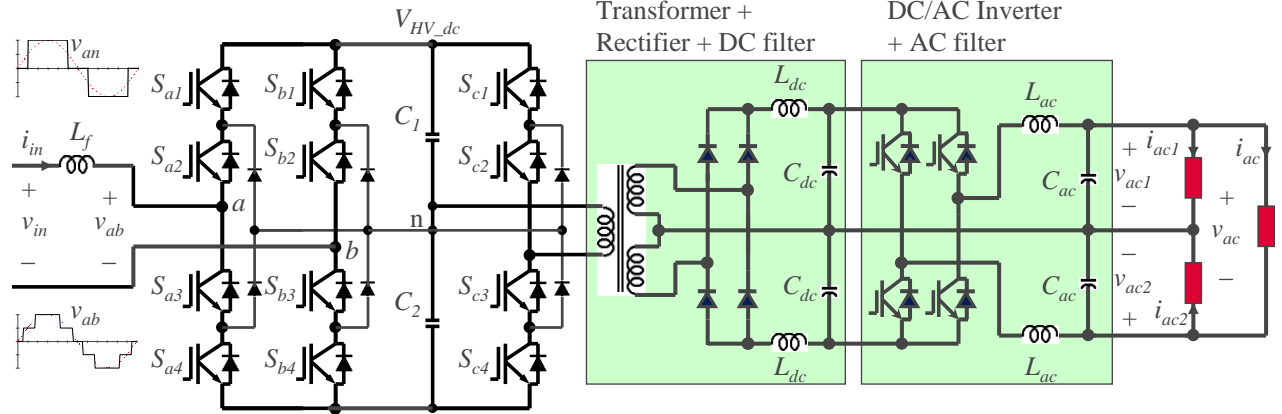


Power System that is Highly Flexible, Resilient and Connected and Optimizes Energy Resources

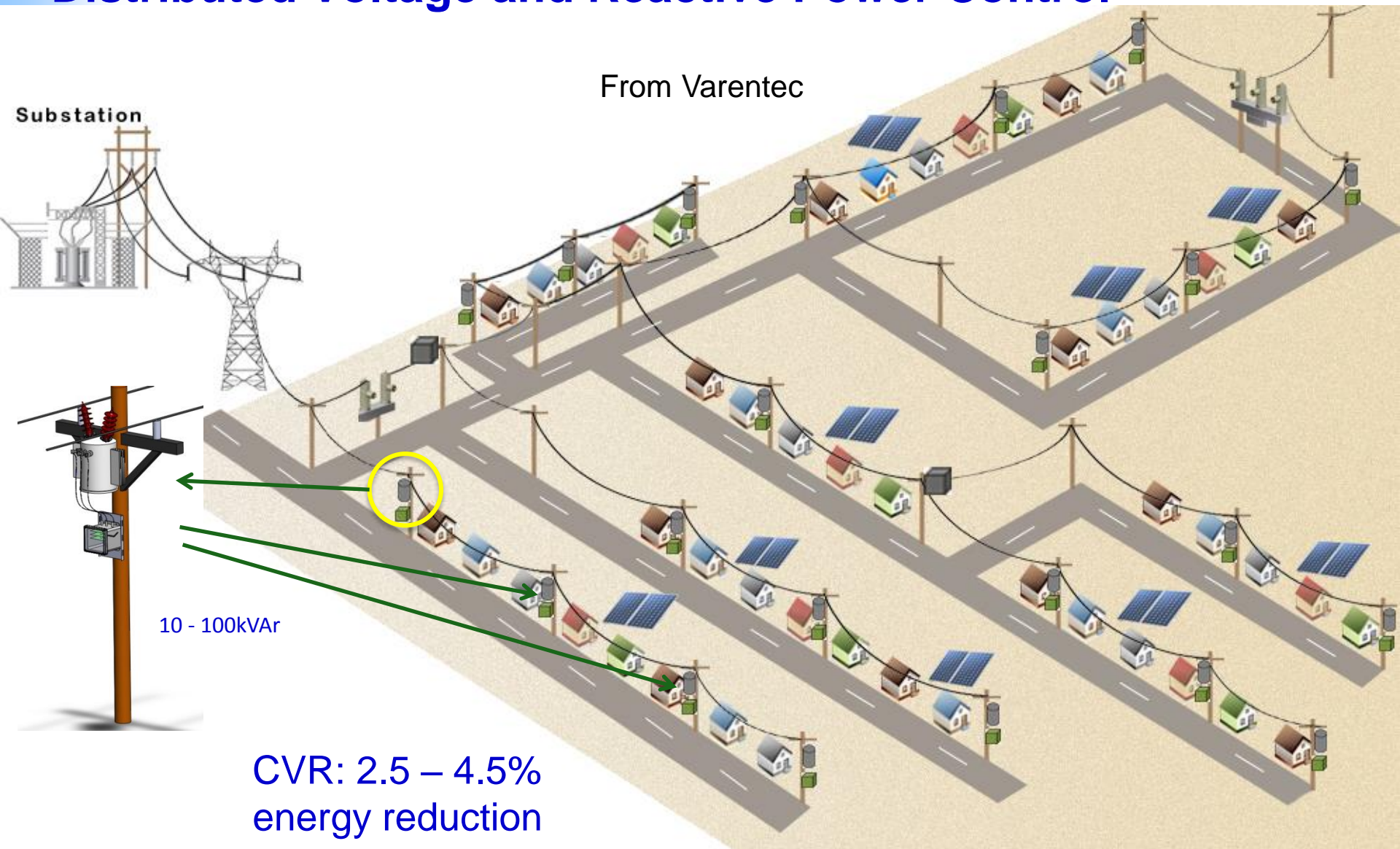
Challenge – Distributed Control Systems



Challenge – Power Electronics Everywhere



Challenge – Distributed Voltage and Reactive Power Control



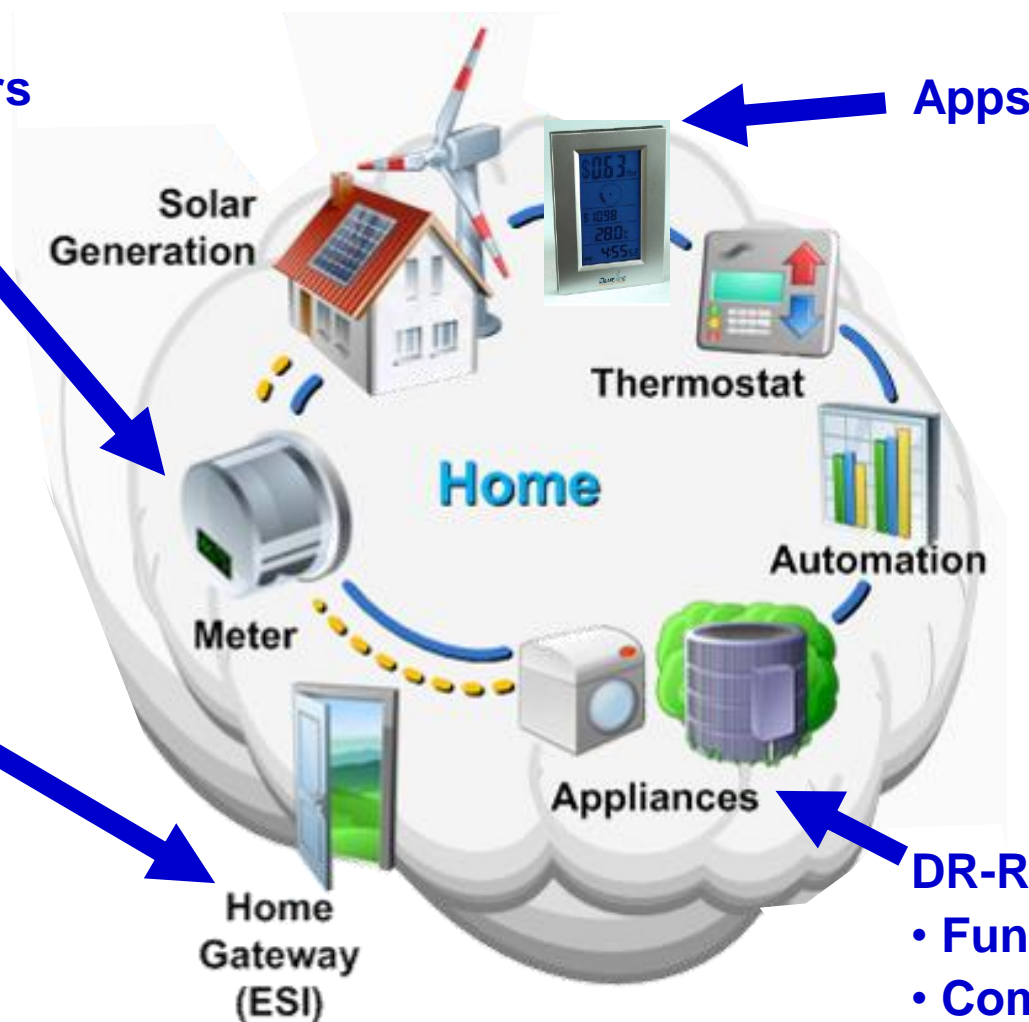
Challenge – Integrating the Customer

Advanced Meters

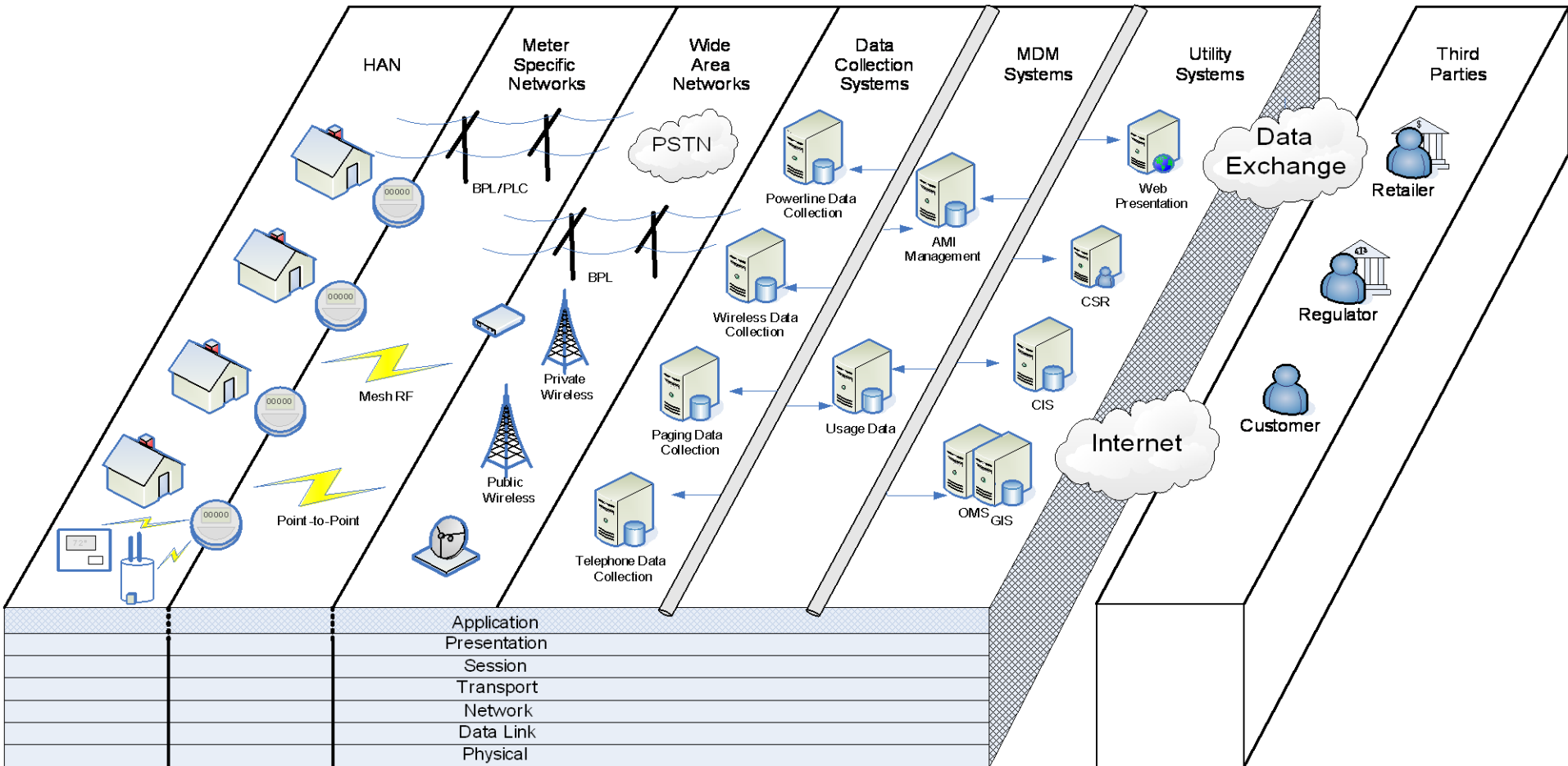
- Energy Mgmt
- Security

Gateways

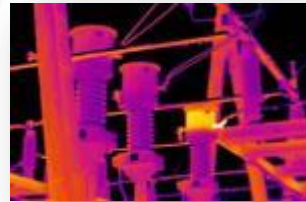
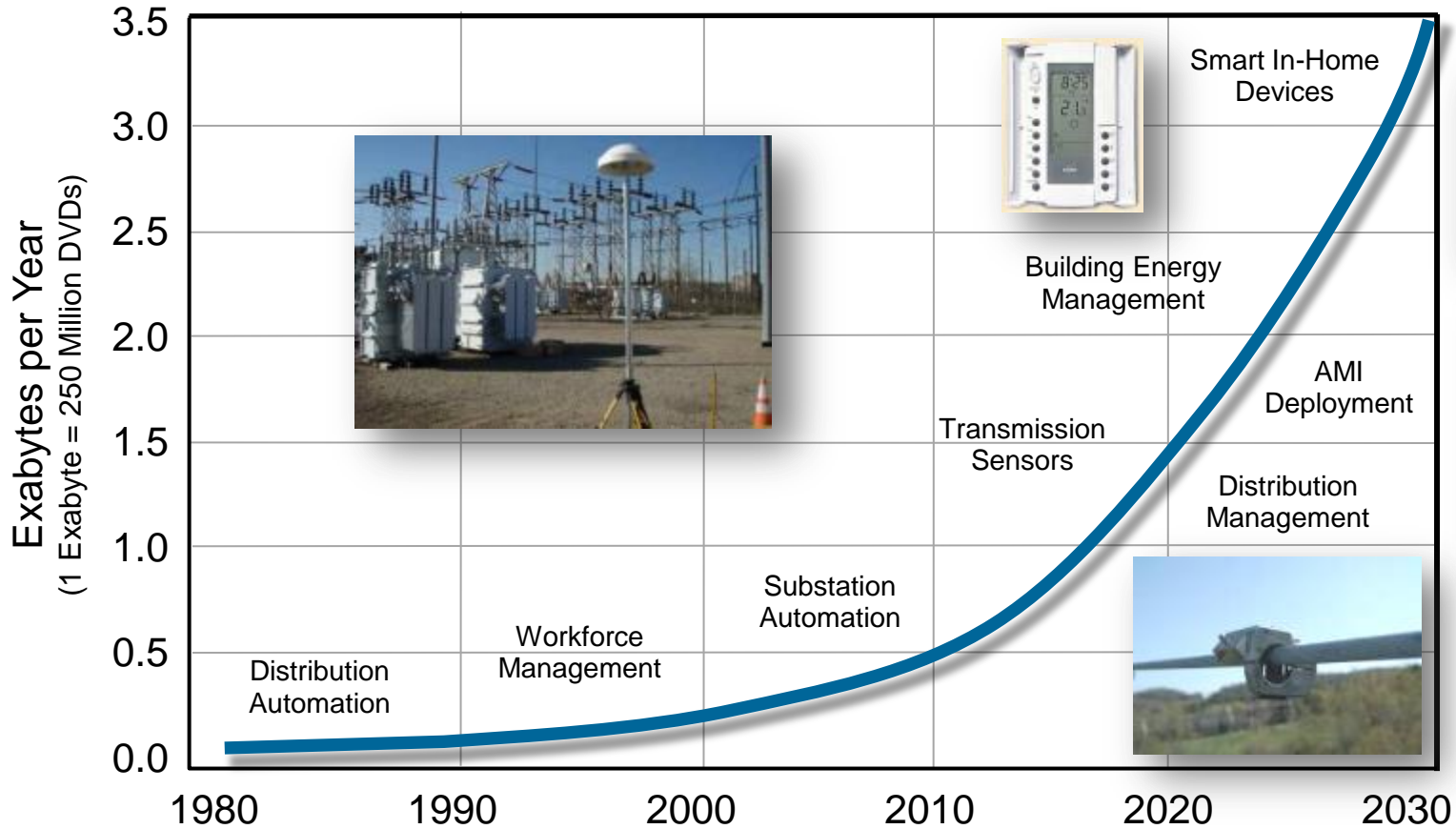
- Custom Box
- Smart Circuit Breaker Panel
- PC/Router



Challenge - Communications Infrastructure



The Era of “Big Data”



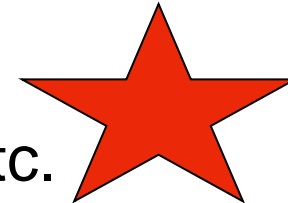
Challenge is Cyber Security – Opportunity is Data Mining

Can We Make it Work?

How Do We Know?

Dist Sys Analysis Needs Envisioned by EPRI (2007)

- Sequential time simulation
- Meshed network solution capability
- Better modeling of Smart Grid **controllers**
- Advanced load and generation modeling
- High phase order modeling (>3 phases)
 - Stray voltage (NEV), crowded ROWs, etc.
- Integrated harmonics
 - NEV requires 1st and 3rd
- User-defined (scriptable) behavior
- Dynamics for DG evaluations
- Distribution State Estimation (DSE)



Other Key Challenges

- Merging Planning and Real-Time Analysis
- Very Large System Models (1M buses)
- Large Volume of AMI Data
- AMI-based Decision Making
- Detailed LV/Secondary Modeling
- Including multiple feeders, transmission
- DG Integration and Protection
- Generator and Inverter Models for DSA
- Regulatory Time Pressures (Screening Tools)

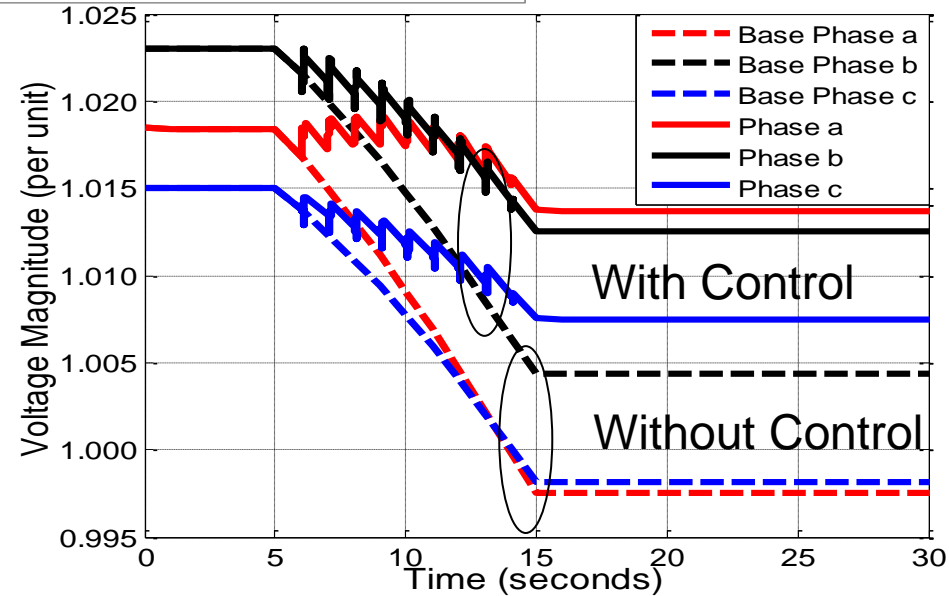
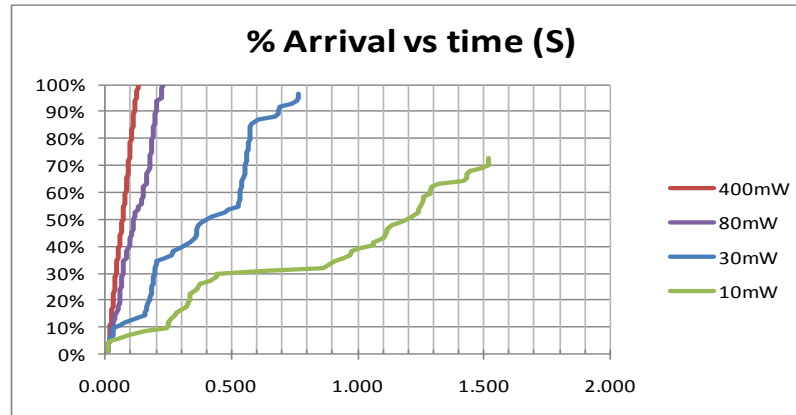
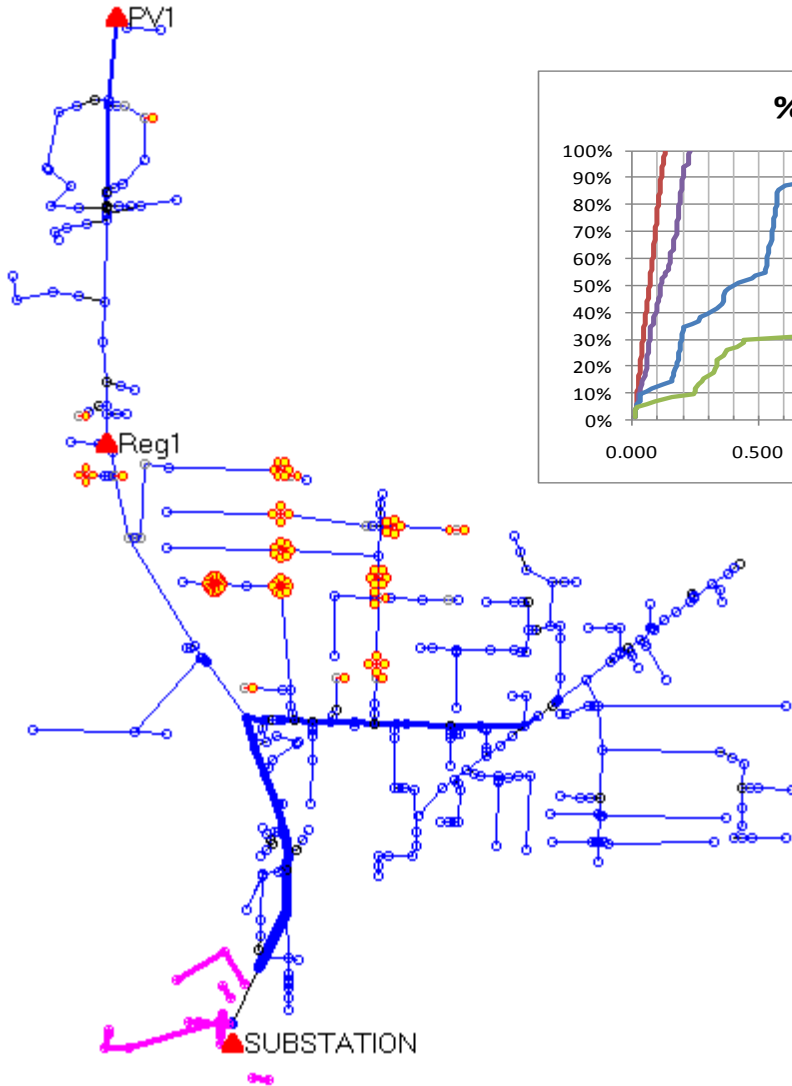
A Large Gap in Distribution Planning Tools ...

- **Co-Simulation of Power and ICT Networks**
- **Distribution System Analysts**
 - Assume ICT system works
- **ICT Network Analysts**
 - Assume power distribution devices work
- Few tools (if any?) for utility distribution planners to determine whether or not the combined system will work!

What EPRI Has Done ...

- Dugan, Mullen, Godfrey, Rodine “Hybrid Simulation of Power Distribution and Communications Networks”, CIRED 2011, Paper 1169
 - Also, IEEE Comm Soc Paper, Oct 2010
- Hypothetical simulation of using 84 Community Energy Storage (CES) modules to compensate for solar ramping with 1-s samples ...

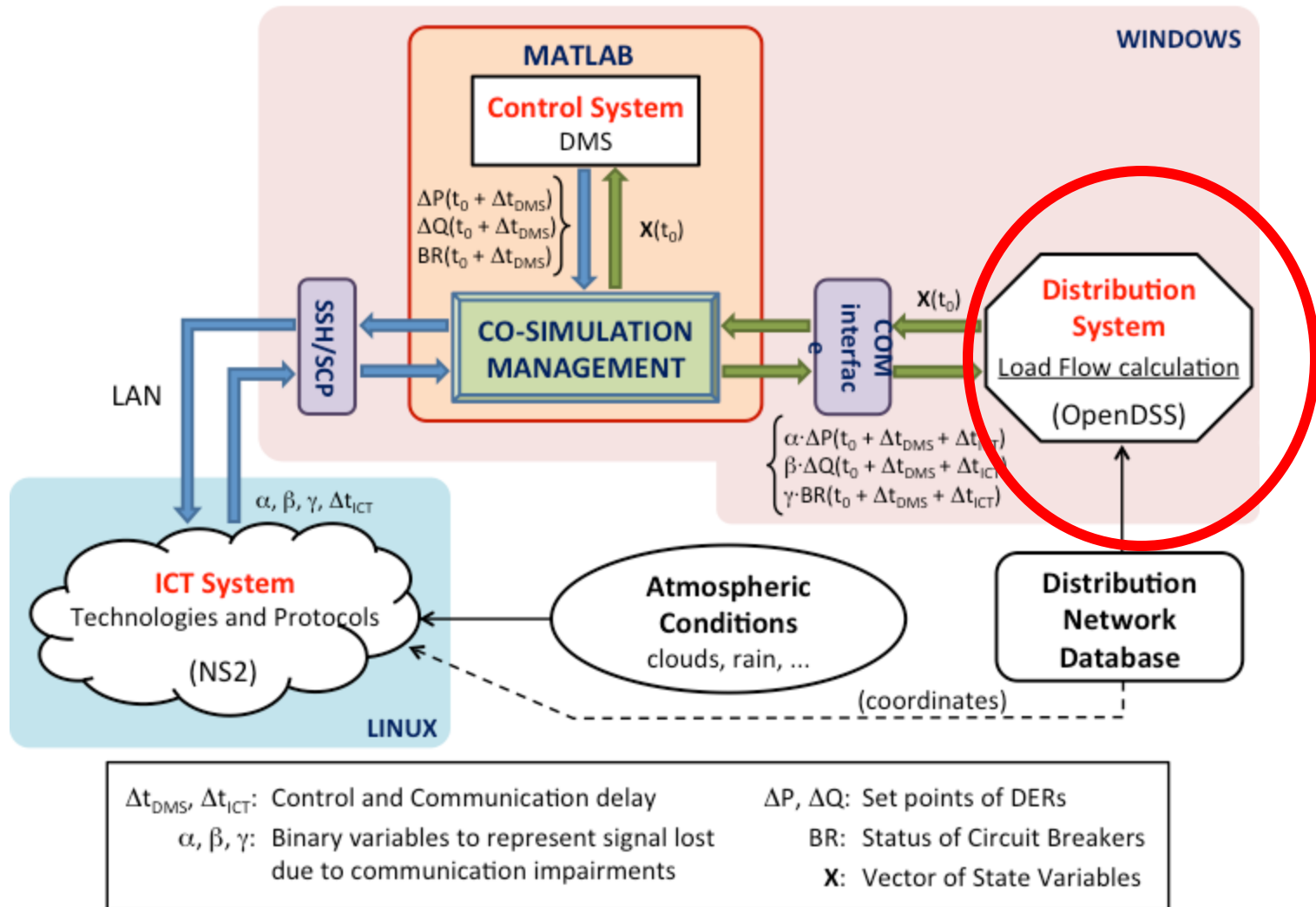
Hybrid Simulation of Power Distribution and Communications Networks – 2010-2011



CIRED 2013 Panel

- **“Joint simulation of cyber infrastructure and power system for smart grid planning and operation studies”**
- **Roger Dugan, Chair**
 - **Mathias Ekstedt** – KTH (Cyber Risk Assessment)
 - **Craig Bredan** – Smarter Grid Solutions (UK) (Active Distribution Network Test Bed)
 - **Oliver Gehrke** – DTU (Co-simulation of power systems, controllers and control infrastructure)
 - **Fabrizio Pilo** – U. of Cagliari (Models and tools for ICT simulation in Active Distribution Networks)

U. Of Cagliari (Italy) Co-Simulation Environment



EPRI's Research on this Subject

- OpenDSS – Open Source Distribution System Simulator
 - Designed for research on distribution system analysis methods for DG and Smart Grid
 - Heavily used now for Solar PV impacts simulations
 - Available (for free) on Sourceforge.net
 - See <http://smartgrid.epri.com/SimulationTool.aspx>
- ICT Research Portfolio
(Matt Wakefield – mwakefield@epri.com)
 - <http://portfolio.epri.com/Research.aspx?sld=PDU&rlid=277>
 - See also: Smart Grid Resource Center:
 - <http://smartgrid.epri.com/Index.aspx>

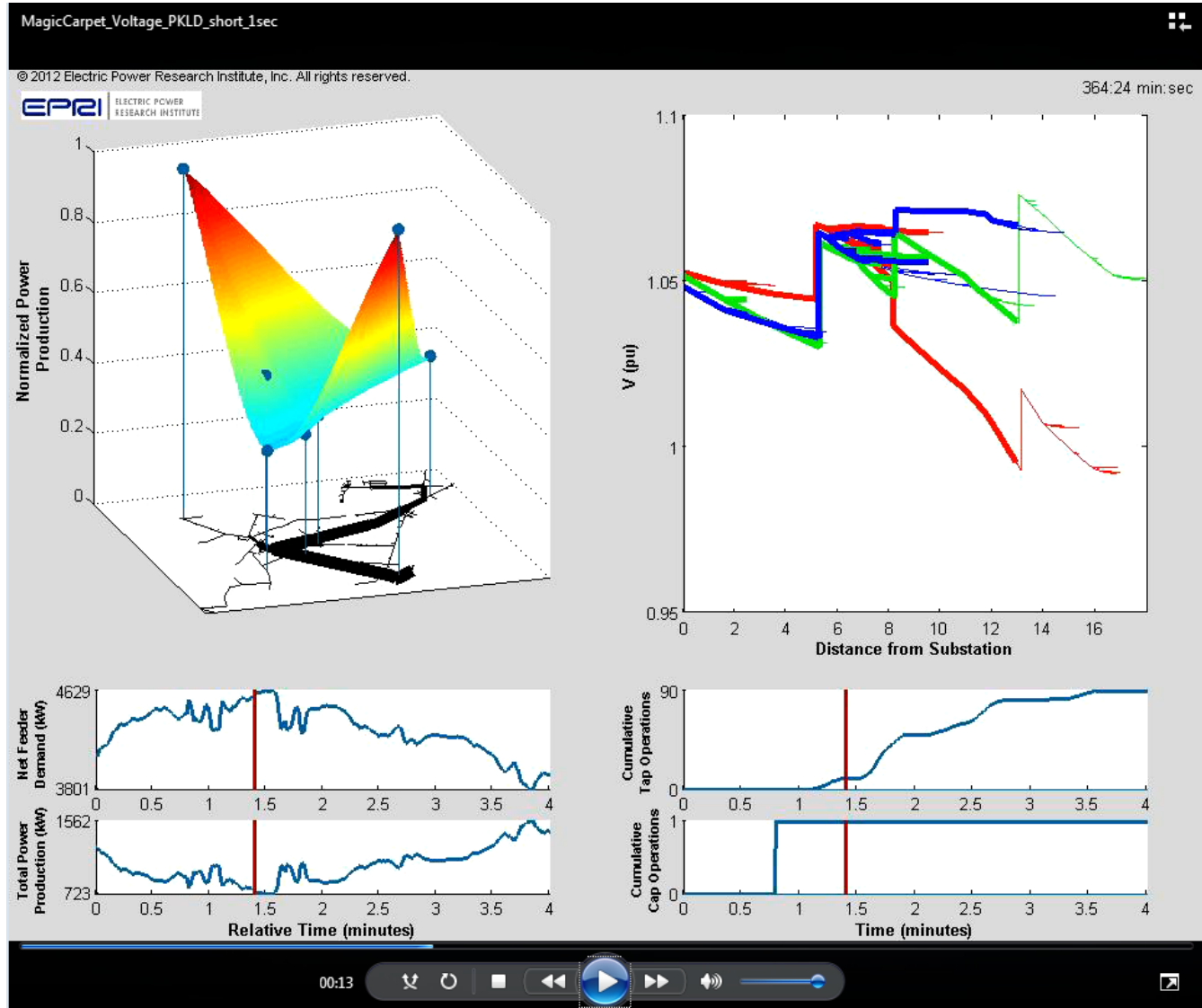
Other Resources and Contacts ...

- John McDonald – Dist. Engineer @ EDF R&D
- IEEE ISGT Europe
 - Committee on ICT Co-Simulation
 - Panel at ISGT-Europe in Oct 2013
 - Kai Heussen – DTU
 - Dr. Heiko Englert – Siemens
 - Steffen Schütte – OFFIS (DE)
 - Thomas Strasse (Austria)
 - And many more ...
- Interest in US is not yet as great
 - But is accelerating rapidly – Panel at IEEE ISGT 2014

An Example of One Problem...

(Cloud Passing over Distribution Feeder Containing Solar PV Generation)

(Movie
Demo –
Time
permitting)





Together...Shaping the Future of Electricity

“We will see more changes in the next ~~20~~ 10 years than we have in the last 100 years”