Cyber-Physical Systems and Future Electric Energy Systems: One and the Same?

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Basic vision for the 4th CMU Conference

- Two seemingly unrelated themes
- Our EESG group (http://www.eesg.ece.cmu.edu) views these two areas as fundamentally inter-dependent.
- Much of our education and research is at this cross-section.
- Cyber is used to enable once passive physical networks to manage a synergic mix of both the existing resources, and many unconventional energy resources.
- Objectives of future energy systems very different from the objectives of traditional utilities ([1])

Basic vision for the 4th CMU Conference

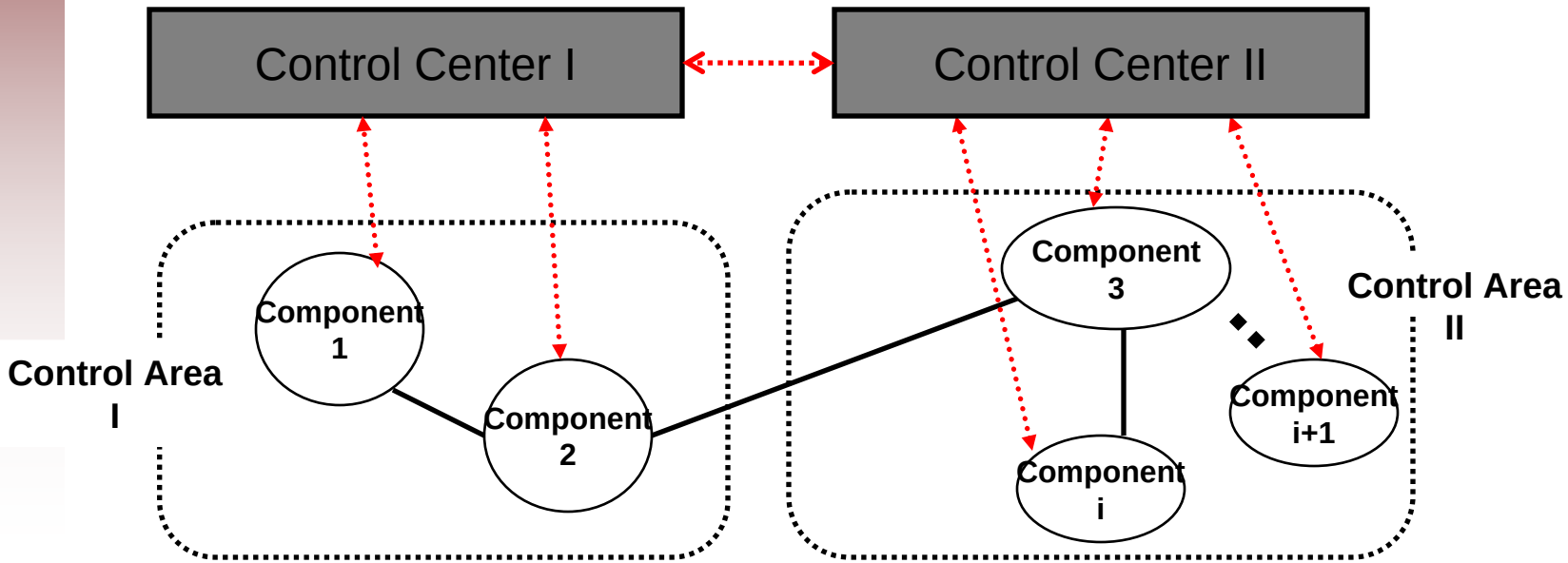
- **Qualitatively different IT infrastructures required to support different physical architectures.**
- **Complexity and cost of cyber for physical systems such as future energy systems can be significant.**
- **Lack of well-defined incentives for converting today's power grid to a user-friendly enabler of future energy systems.**
- **New notions of economies of cyber-physical systems and supporting policy design for ensuring intended performance of future energy systems are needed.**
- **In what follows, some illustrations of current and evolving energy system architectures and possible IT architectures.**

Cyber-Physical Model of Future Energy Systems[2]

A complex network model interconnecting sub-models. Some sub-models are based on the physical principles, and others are inferred based on extensive data processing. Network—comprising multiple sub-networks (some physical and some cyber).

- The most difficult questions concern design and utilization of cyber for providing future electric energy services.
- Numerous examples of poor efficiency, reliability, security (short term) and inadequate evolution of energy systems (long-term) caused by a lack of right IT.

Today's SCADA

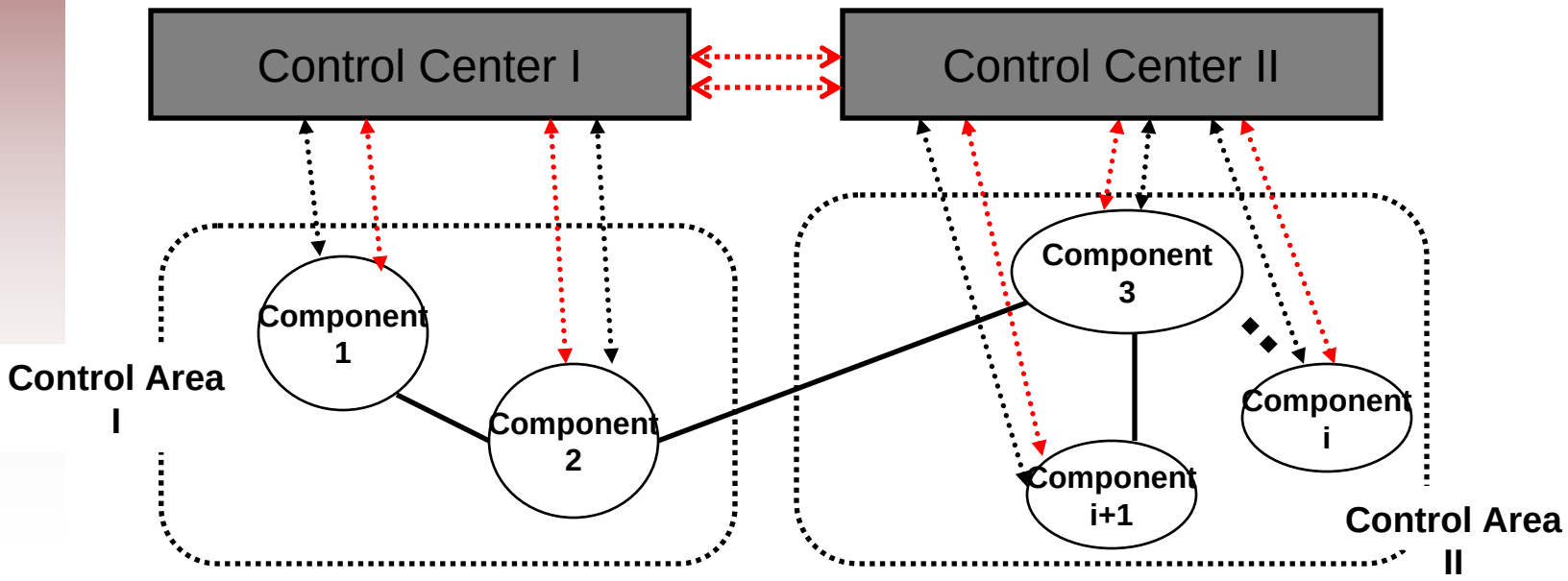


Slow-centralized IT for scheduling

No fast communication for stabilization

No Adaptive local control

Modular Integration of New Resources (Wind) Within Today's SCADA [3]



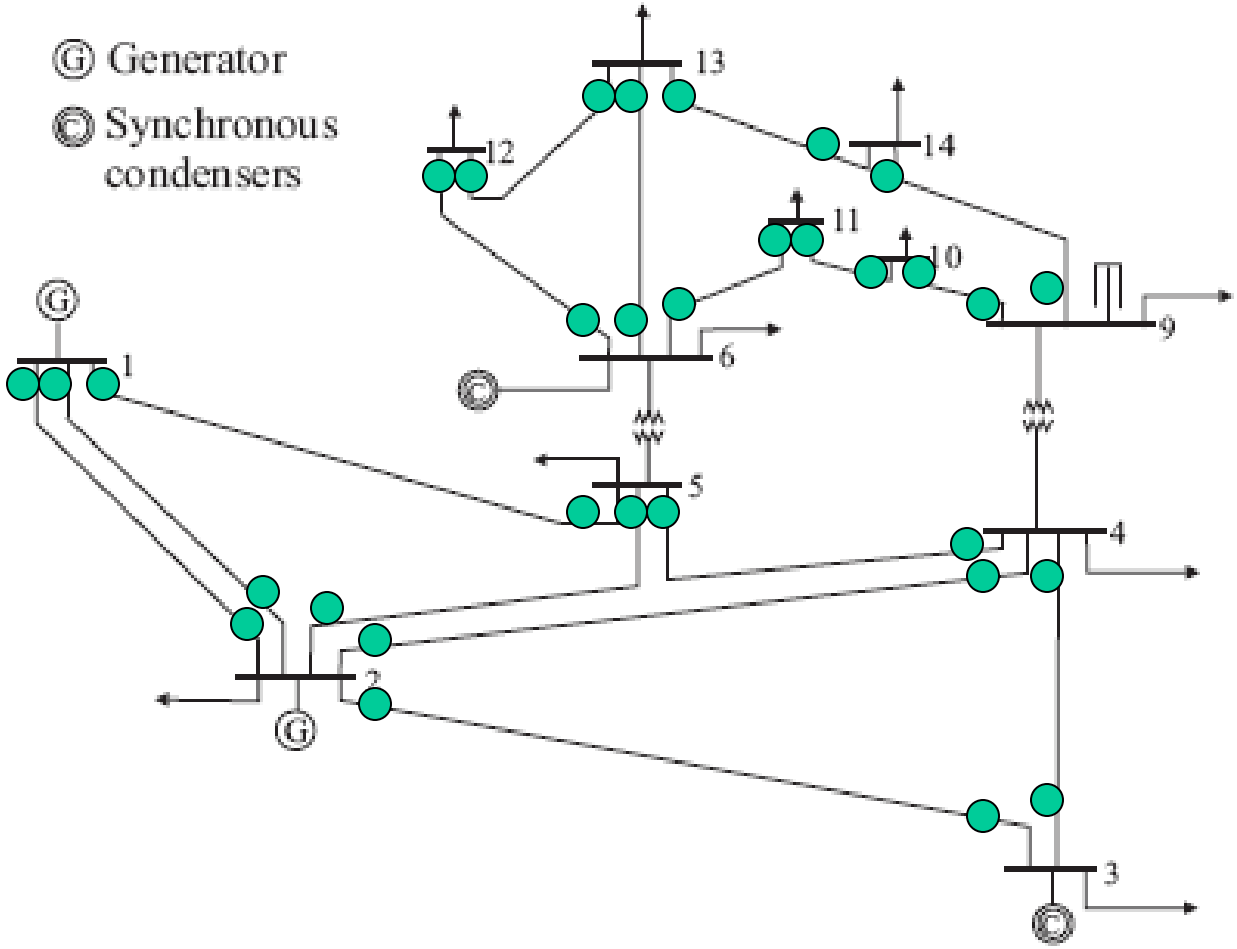
Interaction

——— Physical

---------- Cyber for scheduling (SCADA, slow)

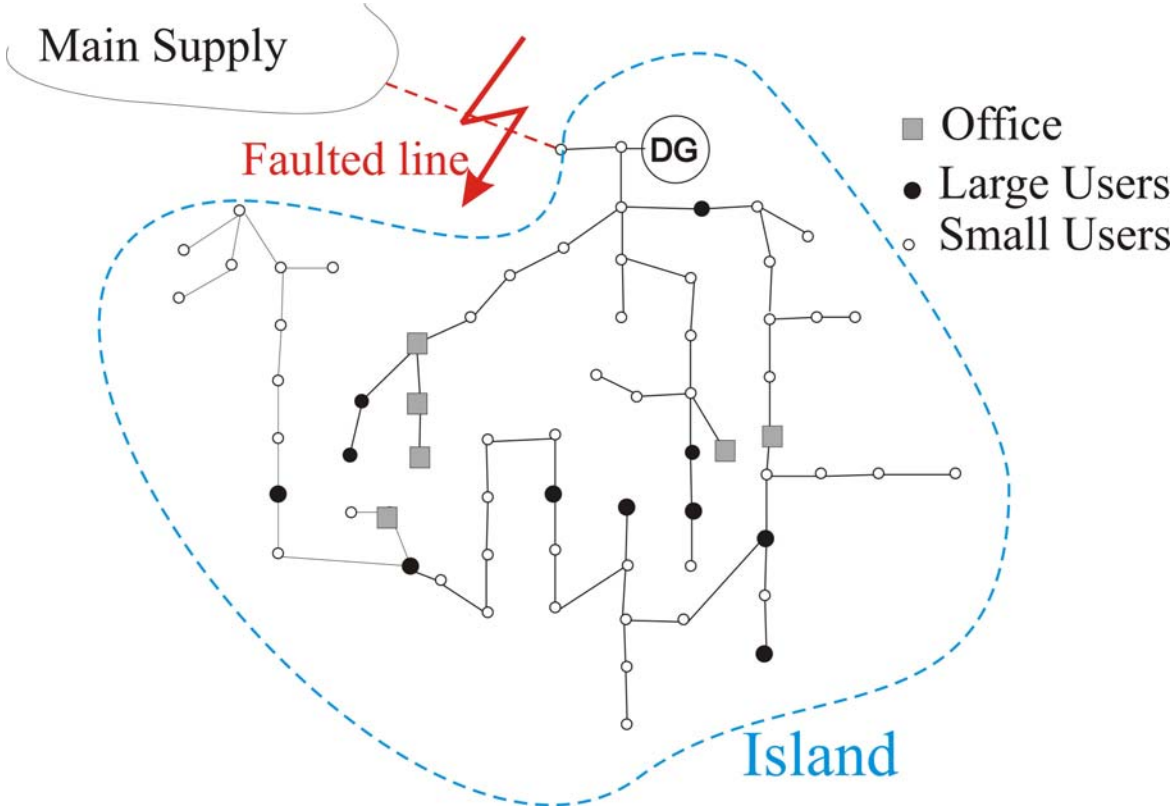
---------- Cyber for control (SCADA, slow)

Local Protection Intelligence for Preventing Blackouts [4,5]

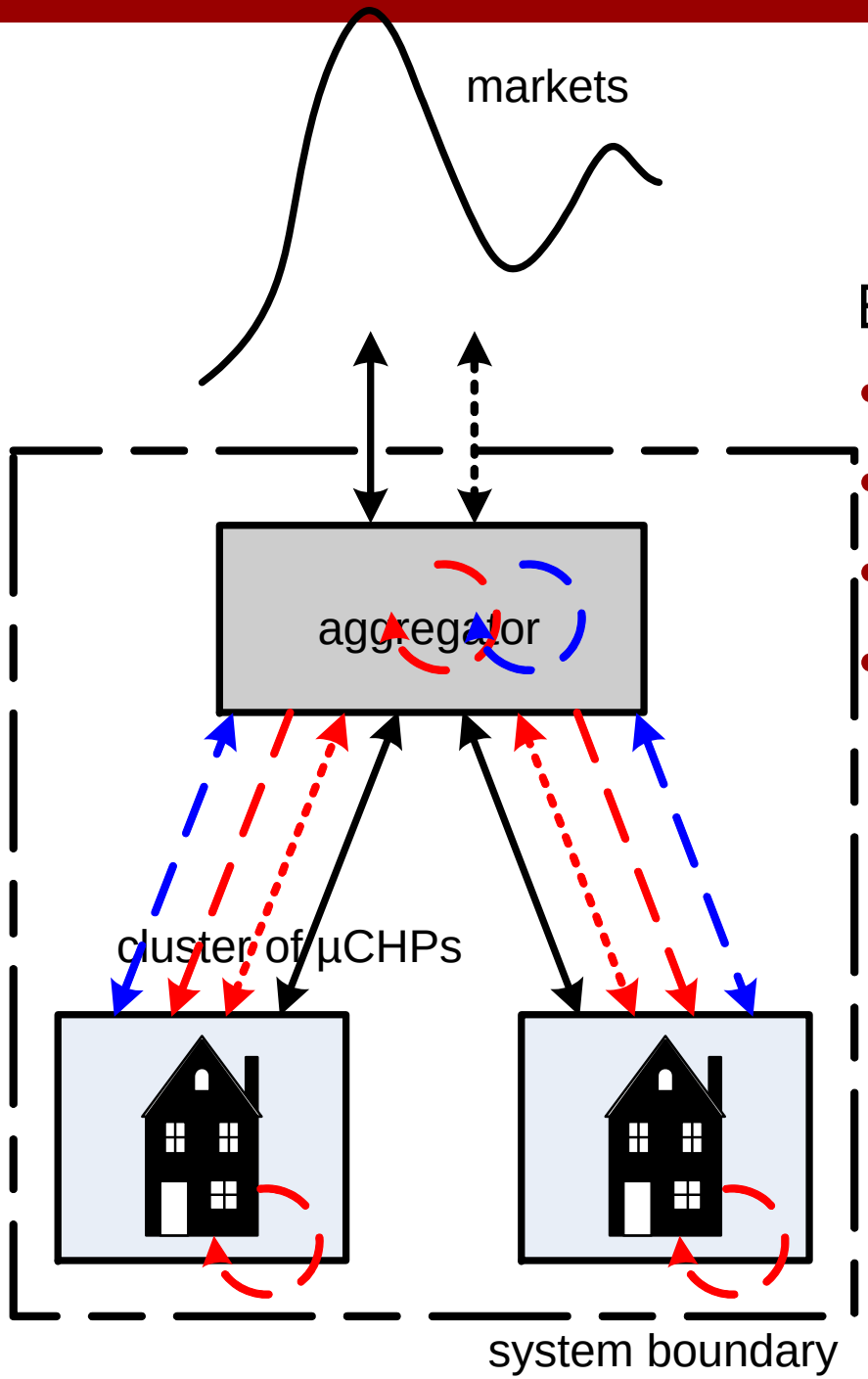


- stands for the location of Support Vector Machine (SVM) Classifier- based protection relays

Maximizing Reliable Service by Coordinated Islanding and Load Management



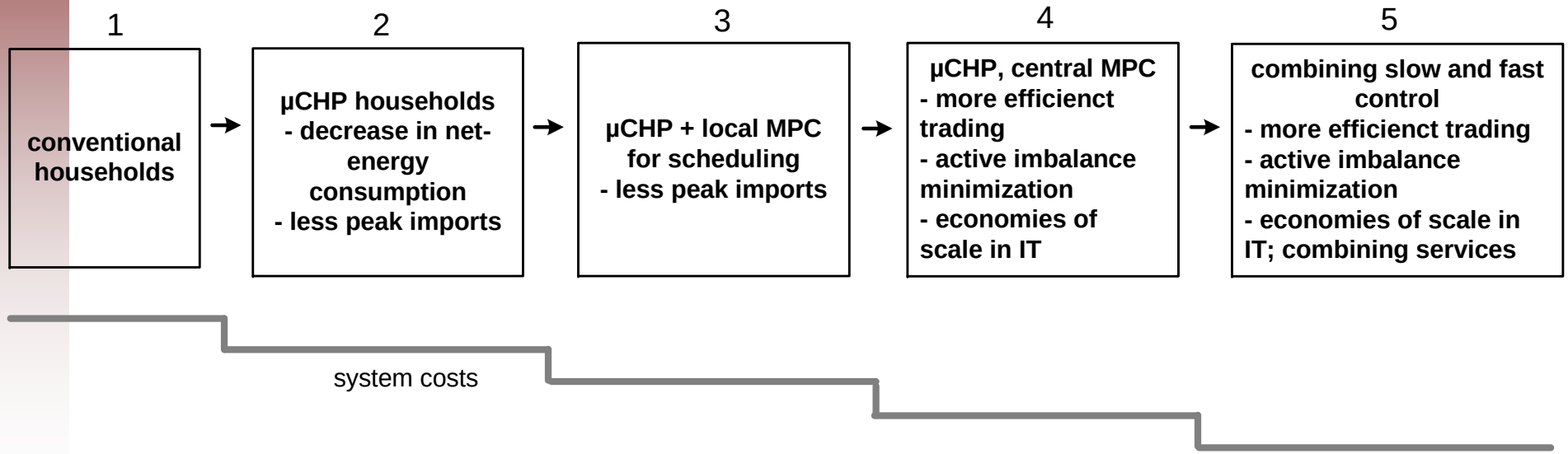
Marija Prica and Marija Ilić [6]



EMPOWERING THE END USERS [7,8]

- µCHP; 'plug-n-play'
- Local MPC
- Central MPC for trading
- Combining slow/fast control

physical
economic scheduling
information
stabilizing control (fast)
information (fast)



- Economies of system in coordination and IT [9]

Conclusions

- Beyond SCADA
- Huge R&D challenge for aligning cyber to support short-term performance of modern electric energy systems and their long-term evolution.
- Cannot proceed with deep science for scavenging difficult-to-get energy resources without developing deep science of cyber-physical systems in support of their most effective integration and utilization.
- Much new needed (spatial, temporal aspects of information processing for meeting specific objectives; relating to properties of physical systems and their performance objectives.)
- Possibly the most immediate and critical are: (1) right incentives; and (2) new generation workforce capable of implementing the change.

References

- [1] Ilic, M., 3rd CMU Electricity Conference, 2007.
- [2] Ilic, M., Xie, L., Khan, U., Moura, J., Cyber-Physical Modeling of Future Energy Systems, IEEE PES Meeting, Summer 2008, Pittsburgh, PA.
- [3] Xie, L., Ilic, M., "Module-based modeling of cyber-physical power systems," *First International Workshop on Cyber-Physical Systems,* June 2008, China.
- [4] Yi Zhang, Marija D. Ilic, and Ozan K. Tonguz, "Application of Support Vector Machine Classification to Enhanced Protection Relay Logic in Electric Power Grids", in *2007 Large Engineering Systems Conference on Power Engineering (LESCOPE06), Montreal, Quebec, Canada October* 10 to 12, 2007
- [5] Patent: Yi Zhang, Marija Ilic, Ozan K. Tonguz, *Support Vector Machine Classification-Based (SVMCB) Mechanism for Smart Protection Relays in the Electric Power Grids,* (Provisioned patent), filed, 2008.
- [6] Prica, Marija, PhD thesis in progress, ECE, Carnegie Mellon Univ, 2009.
- [7] Houwing, M., Delft University.
- [8] Nazari, M., Ilic, M., 4th CMU Conference, White Paper, 2008.