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](http://www.eesg.ece.cmu.edu)) views these two areas as fundamentally interdependent.
- 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.
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

Control Center I

Component 1

Component 2

Control Area I

Control Center II

Component 3

Component i

Component i+1

Control Area II

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

Clusters of μCHPs

markets

aggregator

system boundary

classifier

physical

economic scheduling

information

stabilizing control (fast)

information (fast)
Economies of system in coordination and IT [9]

1. Conventional households
   - μCHP households
     - decrease in net-energy consumption
     - less peak imports

2. μCHP + local MPC for scheduling
   - less peak imports

3. μCHP, central MPC
   - more efficient trading
   - active imbalance minimization
   - economies of scale in IT

4. Combining slow and fast control
   - more efficient trading
   - active imbalance minimization
   - economies of scale in IT; combining services

System costs
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