Position Statement of Energy Cyber-Physical System (CPS) Research

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Cyber-Physical Overlay Networks of Transactive Energy Management & Control

As the electric system continues to transform from a centrally managed, deterministically modeled system to an increasingly distributed collection of energy resources (supply, storage and demand), it requires both a rich cyber-physical system infrastructure, and a complementary distributed energy resource (DER) management model to fully leverage the flexibility and resource efficiency possible from such a system. Transactive Energy Management (TEM) is an approach that uses economic value-based signals as the primary control signal in a distributed management overlay network on the grid. An initial prototype of such a Cyber-Physical Transactive Energy Management Overlay Network has been implemented on the Pacific Northwest Smart Grid Demonstration Project. This work establishes a baseline for what can be achieved, but it's only a starting point. The Workshop will provide an excellent venue to explain our current prototype, and to explore future directions with other attendees.

From a cyber-physical systems perspective, our focus includes several key themes:

- **Large Distributed Energy CPS at Internet-scale**: the key question asked in this research is how to scale and compose thousands or millions small or sub CPS systems of embedded and industrial control devices to build Enterprise Distributed CPS (D-CPS) for end-to-end Transactive energy management system. Our research addresses issues of system of systems composition, interoperability and standards which are key requirements to integrate thousands heterogeneous energy CPS systems and to achieve end-to-end (local and global) optimization objectives in both cyber and physical domain of power grid using Transactive energy as control overlay network.
- **Cognitive Energy CPS with Real-Time Predictive-Analytics:** In the domain of cyber, we are entering a new era of predictive-analytics and cognitive computing due to massive availability of digital data in both volume and rate of collection. Big-data analytics, predictive analytics, machine deep-learning and cognitive computing are forefront innovative technologies in cyber side of system. With the marriage of cyber and physical and availability of big-data from physical world due to massive sensor deployment, we believe that predictive-analytics will be pushed and integrated ever closer to physical side of CPS. At its technology core, TEM is about real-time predictive-analytics of electric energy resources (load, generation and renewable, etc.) and assets and computing economic value-based signal as control signal to manage such resource and interact with neighboring systems in the network. As a research project, it is both interesting and challenge to investigate how to use TEM overlay network to build a fabric of real-time predictive-analytics cross both cyber and physical of energy system and to integrate different kinds of control loops (physical, human, business, social and economic) at grand internet scale.
- **Model-Driven Design and Development of CPS:** this research focus on new information and programming model of CPS with declarative, model-driven approach. The outcome from these research bridges gaps of computation models between control system based on embedded and industrial PLC/SCADA technology and IT system based on general purpose computing technology. As the boundary between cyber IT system and physical control system becomes more blurred and overlapped, we explore promotion of distributed computing services, middleware in cyber IT system to embedded physical control system. On the other hand, our research work introduce and promote computing model and technics used by conventional control system such as real-time, time-dependent & based computing, feedback-loop computing into cyber computation domain.