NSF - Energy CPS Position Statement
Towards a Cyber Physical Model for Smarter Critical Infrastructure

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Smarter buildings, campuses, smarter cities and smarter infrastructure in general, are all coming closer to reality with advances in information technology, large scale data analytics and cloud computing. The “smart grid” and the energy sector have recently attracted a lot of attention. They represent a very appealing but also a very challenging area, where IT and energy converge.

A domain of very particular interest appears to be that of “critical infrastructure”. Infrastructure such as government buildings, hospitals and airports present emblematic examples of large scale complex systems where both energy and IT systems need to operate in unison while providing a large degree of resilience.

In our research group we have a track record of research in the area of smart grid communications. We are emphasizing the modeling of energy storage and the optimal control for EV charging infrastructure. And we have introduced the explicit **coupling** of communications and energy aspects of objective functions in smart buildings.

Regarding smart critical infrastructure, we propose to focus on medical centers that contain clinical wards, outpatient facilities, intensive critical units, and laboratories. Hence, they represent a complex entity with dozens of diverse stakeholders, varying scales in terms of size and complexity of their operations. Further, the presence of such centers across the country and the world is ubiquitous, but it cannot always be assumed that a dedicated power line with “high quality” of service be supplied to them.

Given their operations complexity and priorities, they have to prioritize layer by layer both their physical, as well as cyber components in terms of being “secure” and reliable. Further, since medical centers possess and use critical infrastructure for patient care and research, both the cyber aspects and “physical” in terms of equipment management and power management including energy storage systems (ESS) come into the picture together with optimization schemes

Therefore, the broad objective of this project is to delineate *design*, *modeling* and layered *control strategies* for critical infrastructure systems equipped with ESS. To achieve this goal, expertise in power electronics, communications, control, and analytics is needed. Further, we plan to use the medical centers as a case study for design and validation purposes.

Note that if this problem can be effectively understood and addressed, then the resulting methodology can serve as a canonical paradigm for other critical infrastructures, including microgrid management in military bases and off-base (battlefield) camps, and airports. Thus, this research direction can have broader impact and importance/relevance.

We propose a tiered system comprised of the following modules: (i) profiling, (ii) load scheduling, and (iii) communications. Broadly, the objective of the profiling module is to collect information about different user profiles at different spatial (buildings, floor, laboratories, etc.) and temporal scales. The load scheduling module's goal is to integrate online measurements from various smart meter devices deployed throughout the medical center, forecasted demand gleaned from the long-term data obtained and processed from the profiling module and schedule the ESS devices. Finally, the role of the communications module –the central command in our framework- is to gather and disseminate the necessary information from and to the other two modules.

The effectiveness and, most important, the resilience of this communication system will be crucial: It will be essential for the layered control structure of the critical infrastructure. At the heart of our "cyber physical" model will lie our novel, explicitly coupled objective functions and constraints, which will combine the computing and communication resources ("cyber" portion) with the energy utility functions ("physical" portion). The cyber portion will deal with the computing and communication required to execute the control algorithms in real time.

This will be especially relevant as the system scales up and as the quality-of-experience or "grade-of-service" and reliability values become progressively much tighter. Our aim is to model the optimization of the computing and communications resources, jointly with the resources needed by the "physical" actuation, namely the energy allocations, temperature settings, critical equipment control and storage decisions.

The expected outcomes of such a project would include: (1) A large scale simulation and emulation model comprising of the profiling, load scheduling and communications modules. It would provide a rich platform for researchers from different domains carry out research in diverse fields, including power electronics, communications and control algorithms and data analytics. (2) A set of best practice *blueprints* for a University size medical center (with an accurately characterized customer base through user surveys). (3) A set of engineering design principles for tiered architecture of ESS equipped buildings. (4) Algorithms for cybercontrol and optimization.