NSF Role in Supporting Innovation in Research and Education in Electrical Power and Energy Systems

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Main Message

We are committed to working with the community to discover and support innovation in electrical power and energy research and education ----

There is currently a great need for advancing such efforts
Electrical Power Networks

- Critical infrastructure for society
- Large scale spatially distributed nonlinear dynamic systems with multiple time scales
- Hierarchical control and management system involving cyber-physical components, sensors, algorithms, and economic markets
- Techno-socio-economic system with multiple stakeholders
- Regulation and policy (and economics!)
Major Trends and Drivers

- Aging infrastructure in developed world and new infrastructure in the developing world
- IHS Global Insight estimates $12 trillion to be spent on electric grid between 2014-2020
- The rise of distributed generation (DG) and microgrids
- Integration of renewable electric energy from wind and solar, including independent “prosumers”
- Changing demand profiles
- Increasing natural gas generation
- Need for greater resilience in the face of natural and man-made disasters
- Cybersecurity

- All of these challenges require greater power system innovation and a new generation of power system engineers with broad and deep training.
Power System Planning and Operations w/ DG

• Power systems with DG do not behave like traditional power systems; new questions arise:
  – Stability criteria for traditional power networks do not carry over to systems with significant penetration of renewable sources.
  – Mandated feed-in tariffs (apply even if the power isn’t needed).
  – Lack of storage means that the utility may have to pay for power it doesn’t benefit from.
  – No economic policy to cover utility costs to support voltage at DG sources (newer DG sources add to the financial stress; should they pay more than earlier deployed DG?).
  – How to price high variability power sources (solar, wind)?
  – Demand response design (“demand dispatch”).
ENG and SBIR/STTR Research Budgets ($M)
Engineering Research Centers (Energy Related)

- Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)
- Center for Ultra-Wide Resilient Electric Energy Transmission Networks (CURENT) – joint with DoE
- Quantum Energy and Sustainable Solar Technologies (QUEST) - joint with DoE
- Smart Lighting
- New ERC Competition underway
Industry-University Cooperative Research Centers

- Power Systems Engineering Research Center (PSERC)
- Energy-Smart Electronic Systems (ES2)
- Energy Harvesting Materials and Systems (CEHMS)
- Grid-Connected Advanced Power Electronic Systems (GRAPES)
- Advanced Vehicle and Extreme Environment Electronics (CAVE3)
- Novel High-V/T Materials and Structures (HVT)
- Next Generation Photovoltaic
- Silicon Solar Consortium
- Wind Energy Science, Technology and Research (WindSTAR)
EPCN Program Description

- Control Theory and Hybrid Dynamical Systems
- Networked Multi-agent Systems
- Cyber Physical Systems Modeling and Control
- Control/Optimization in Buildings, Transportation, and Robotics
- Adaptive and Intelligent Systems; Neural Networks
- Energy Harvesting, Storage Devices and Systems
- Solar and Wind Energy and Integration of Renewables with Grid
- Monitoring, Protection and Cyber Security of Power Grid
- Advanced Power Electronics and Electric Machines
- Electric and Hybrid Vehicles; Integration with Grid
- Policy, Economics, Consumer Behavior and the Power Grid
- Quantum, Molecular and High Performance Modeling and Simulation for Devices and Systems (QMHP)
Example of Possible Educational Innovation: Open access testbeds

- Massively open online courses (MOOCs) are gaining huge popularity
- Robotics course has ~40,000 students at start
- Desire to open robotics space to the students in the course
- Can we expand upon this idea of a Robotarium?
Need: Research and education access to remote laboratory experience

- “Bare bones” multi-robot laboratory ~ $250k
- Price is a major stumbling block for many universities and groups
- Research and education are performed in isolation
- Resource competition is the norm
Approach: Distributed laboratory space with open access

- Develop and use open-access, online, shared engineering laboratory spaces
- Potential laboratories: robotics, power systems, smart buildings, medical systems, etc.
- Shared cost and leveraging expertise

Benefits: Improving research through better access to resources

- Lessen the cost barrier to engineering experimental research
- Accelerate innovation by getting more talented people engaged
- Harness the power of the network by people working together to reach beyond the traditional, isolationist research model
Benefits: Potential new avenues and research thrusts

- Visualization and Augmented Reality
- Trade-offs of cyber security and networking
- Cyber physical systems – interaction of virtual and physical systems
- Formal model checking of software
- Real-time verification of safety systems
- Best practices and trade-offs for distance learning
Benefits: Improving education through better access to resources

- Significantly lower cost for access to expensive hardware
- Make use of exciting developments in robotics, drones, CPS systems, etc.
- Advance the participation of non-traditional and under-privileged students

CPS Security Testbed Federation (ISU, USC, MITRE)
Attack-Defense Demo @ Smart America Challenge Expo

Image: M. Govindarasu, Smart America challenge
Competition: Open-access test beds have been done previously

- ORBIT – wireless research
- DETER – cyber security test bed
- Northern Illinois University – Internet Accessible Remote Laboratory

Images: http://www.orbit-lab.org/, http://www.niu.edu/remotelab/
Summary

- There are many fundamental issues needing study, especially with the increasing penetration of wind and solar sources.
- This is an exciting field for research and innovation, with many interesting open problems.
- We need to find innovative ways to excite a new generation of power engineers with a broad interdisciplinary education.
- NSF wants to work with the community to advance this area and develop the needed workforce.