Electric Energy Systems of the Future - Visions, Challenges, and Opportunities

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NSF ENG: Investing in engineering research and education to foster innovations for benefit to society
Office of the Assistant Director
Emerging Frontiers in Research and Innovation (EFRI)

Engineering Education and Centers (EEC)
- Engineering Centers
- Engineering Education
- Engineering Workforce

Chemical, Bioengineering, Environmental, and Transport Systems (CBET)
- Chemical, Biochemical, and Biotechnology Systems
- Biomedical Engineering and Engineering Healthcare
- Environmental Engineering and Sustainability
- Transport and Thermal Fluids Phenomena

Civil, Mechanical, and Manufacturing Innovation (CMMI)
- Advanced Manufacturing
- Mechanics and Engineering Materials
- Resilient and Sustainable Infrastructure
- Systems Engineering and Design

Electrical, Communications, and Cyber Systems (ECCS)
- Electronics, Photonics, and Magnetic Devices
- Communications, Circuits, and Sensing Systems
- Energy, Power, and Adaptive Systems

Industrial Innovation and Partnerships (IIP)
- Academic Partnerships (GOALI, I/UCRC, PFI AIR, and PFI BIC)
- Small Business Partnerships (SBIR, STTR)

May 8, 2014
Electric Power Systems

- 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
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
- Integration of renewable electric energy from wind and solar
- Need for greater resilience in the face of natural and man-made disasters
- Cybersecurity
Technological Drivers

- Decreasing cost of solar PV
- Novel power electronics devices with significant new capabilities
- Growing deployment of synchrophasors
- Infusion of computing, communications and controls into the physical power system
- Electric energy storage
- Electric and hybrid vehicles
- Fuel cells,
- Natural gas stirling engines - micro generation
- ...
How can (will) the electric grid be transformed into a sustainable, reliable, and economic electric energy system for society?
Electric Power and Energy Research – NSF Role

• Energy, Power, and Adaptive Systems Cluster in the ECCS Division
  – Samir El-Ghazaly, Division Director, ECCS
  – Eyad Abed, Kishan Baheti, and Paul Werbos, program directors

• Energy for Sustainability in CBET Division
  – JoAnn Lighty, Division Director, CBET
  – Greg Rorrer, Bruce Hamilton, program directors

• Cyber-Physical Systems (CPS) [CISE+ENG]

• Science, Engineering and Education for Sustainability (SEES)
  – Sustainable energy pathways (SEP)
Engineering Research Centers

- 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)
Infrastructure Systems – A New Paradigm

• Idea: Rethink infrastructure systems as providing needed services
• Resilient Interdependent Infrastructures Processes and Systems (RIPS)
• Deadline: March 19, 2014

http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504971&org=EFRI&from=home
Eliminate Water Use in Electricity Generation -
An NSF-EPRI Partnership

- Nearly 40% of the freshwater withdrawal in the US is for Thermal-electric power plants; 90% of this is used for cooling.
- EPRI study suggests lack of water in many regions that put nearly 25% of power production at risk.
- Goal of the NSF-EPRI Collaboration: To eliminate or minimize the use of water for cooling in Thermal-electric power plants. Likely impact will be very significant in terms of water availability for other sectors.
- Twelve projects exploring novel transformational ideas funded at universities with industry participation/oversight; NSF & EPRI contribute equally.
Energy Harvesting

- Objective: Recover waste heat; automobiles; industrials; buildings
- Potential Impact: In 250M automobiles, Thermoelectrics can be used to convert waste heat to electricity - 5% fuel savings ( $250B)
- Innovations: Materials with improved conversion efficiency, Low cost manufacturing, System design and integration

http://www1.eere.energy.gov/vehiclesandfuels/technologies/engines/solid_state.html

Fairbanks et al. 2010, 2013

2010 NSF/DOE Partnership on Thermoelectric Devices for Vehicle Applications

White House announced new corporate average fuel economy (CAFÉ) standards of 54.5 mpg by 2025
F-PACE: Foundational Program to Advance PV Cell Efficiency

- DoE SunShot: Advanced Solar Photovoltaic (PV) Technologies
- Goal: reduce the total cost of solar energy systems by about 75% before the end of the decade
- F-PACE: DoE-NSF partnership
- Solar device physics, improved PV cell performance, and reduced module costs for commercial applications
  - $38.5M awarded in FY12
Opportunity in Electrical Engineering Education

• Despite tremendous efforts by the engineering education community, major issues stubbornly remain and progress modest

• Retention, diversity, preparation, depth vs breadth vs professional skills, K-12 issues, …

• Can sustainable electric energy theme make a big impact on student and education issues in electrical (and computer) engineering departments?
  – Retention, diversity, enrollments, …

• What kinds of collaborations will be necessary to achieve breakthrough results?

• Could there an alternative track with energy and sustainability theme? Will it be viable and attractive to employers?
Graduate Level Issues

• Smart grid opportunity to modernize the grid

• How can the power systems curriculum be rethought and restructured to bring in students from controls, communications, networking, computing, software backgrounds?

• What are the industry needs?
QUESTIONS?

IDEAS, THOUGHTS!

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