NSF Programs with Electric Power System Activities

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Barbara Kenny
Cyber-Physical Systems (CPS)

Systems in which the cyber and physical portions are tightly integrated at all scales and levels with computing deeply embedded into every physical component. A fully-integrated hybridization of computational, physical and human action.
NSF CPS Program

- **CPS themes:**
  - **Foundations** research to develop new principles, algorithms, models, and theories
  - **Methods and Tools** research to bridge gaps between approaches to the cyber and physical elements of systems through innovations
  - **Components, Run-time Substrates, and Systems** research motivated by grand challenge applications

- 2009: $45M into 58 awards, 8 in Energy & Environment
- 2010: $32M into 43 awards, 5 in Energy & Environment
- 2011: $30M in budget, proposals due in March, 2011

CISE Program Officer: Helen Gill
ENG Program Officer: Kishan Baheti
CPS energy related awards

- “Cyber-Enabled Efficient Energy Management of Structures,” Tyrone Vincent, Robert Braun, Dinesh Mehta, Kevin Moore, Siddharth Suryanarayanan (Colorado School of Mines)
- “A Framework for Enabling Energy-Aware Smart Facilities,” Lucio Soibelman, H. Scott Matthews, Jose Moura (Carnegie Mellon University); Burton Andrews and Diego Benitez (Bosch)
- “Methods for Network-Enabled Embedded Monitoring and Control for High-Performance Buildings,” Prabir Barooah (U. Florida), Alberto Speranzon (UTRC), Prashant Mehta and Sean Meyn (UIUC), Luca Carloni (Columbia)
- “Architecture and Distributed Management for Reliable Megascale Smart Grids,” Junshan Zhang, Vijay Vittal (Arizona State University)
### Program Directors:

#### Electronics, Photonics, and Magnetic Devices (EPMD)

**Dr. Samir El-Ghazaly**
- Microwave/mm-Wave/THz Devices & Circuits
- Novel & Next Generation Devices
- Vacuum Devices & Electronics
- Antennas
- Electromagnetic Propagation & Scattering
- Microwave Metamaterials-Based Devices
- Device /Circuit Simulation & Modeling

**Dr. Pradeep Fulay**
- Flexible & Printed Electronics
- Light Emitting Devices & Displays
- Molecular /Organic Electronics & Photonics
- Energy-Efficient Green Electronics
- Next Generation Memories, Memristors, & other Novel Devices

**Dr. Usha Varshney**
- Bioelectronic & Biomagnetics Devices
- Science & Engineering Beyond Moore’s Law
- Quantum Devices
- Magnetics, Multiferroics, & Spintronics
- Sensor Devices & Technologies

**Dr. John Zavada**
- Optoelectronics & Photonics
- Nanophotonics
- Plasmonics & Optical Metamaterials-Based Devices
- Large-Scale Photonic Integration
- Ultrafast Photonics

#### Communications, Circuits, and Sensing-Systems (CCSS)

**Dr. Zygmunt Haas**
- Cyber-Physical Systems (CPS)
- Embedded Systems
- Wireless Communications Algorithms & Networking
- Integrated Sensing, Communications, & Computational Systems
- Signal Processing & Coding
- Cyber Security

**Dr. Rajinder Khosla**
- Sensors, Actuators, & Electronic Interfaces
- Chemical, Biological, & Physical Diagnostic Systems
- Implantable & Wearable Systems
- Environmental Sensing & Monitoring
- MEMS/NEMS Devices
- System-Level Fabrication, Packaging, & Assembly

**Dr. Andreas Weisshaar**
- RF/Wireless, Optical, & Hybrid Communications
- Broadband & Low Power Communications
- RF/Microwave & mm-Wave Components/Circuits
- Inter- and Intra-Chip Communications & Networking
- Submm-Wave/THz Imaging & Sensing
- Mixed Signal Circuits & Systems
- Enabling Technologies for Intelligent Communications Systems
- Interconnects & Packaging Techniques

#### Energy, Power, and Adaptive Systems (EPAS)

**Dr. Radhakisan Baheti**
- Control Theory & Hybrid Dynamical Systems
- Distributed & Mobile Networked Control
- Systems Theory in Molecular, Cellular, & Synthetic Biology/Medicine
- Estimation in Sensing & Imaging Systems
- Sensor Networks for Energy-Efficient Buildings
- Transportation Networks
- Human-Robot Interaction
- Stochastic Modeling & Applications

**Dr. George Maracas**
- Energy Collection, Photovoltaics, & Thermal Devices
- Novel Energy Conversion Devices
- Renewable Energy Devices & Systems
- Power Conversion, Generators, Motors & Network Interfacing
- Energy & Power Sensing Technologies
- Energy Storage Technologies
- High Voltage, High Power Switching & Conversion Devices

**Dr. Paul Werbos**
- Adaptive & Intelligent Systems
- Transmission & Distribution Systems
- Intelligent Power Grid
- Quantum Systems & Modeling
- Neural Networks
- High Performance & Multiscale Modeling
- Cognitive Optimization & Prediction
- Intelligent Vehicles & Robots
Energy, Power and Adaptive Systems

- Emphasis on electric power networks and grids
  - Generation
  - Transmission and integration of renewable, sustainable and distributed energy systems
  - High power electronics and drives
  - Associated regulatory and economic structures

- Topics of interest
  - Alternate energy sources
  - Smart Grid
  - Interdependencies of critical infrastructure in power and communications
Sample EPAS projects

- “Tools for assessment of transmission-constrained market power in electricity markets,” Ross Baldick, UT-Austin
- “Multiple FACTS devices coordination using synchronized wide area measurements,” Yilu Liu, University of Tennessee, Mariesa Crow, MST
- “Dynamic grid control using virtual quadrature sources,” Deepak Divan, Ronald Harley, Georgia Tech
- “Transmission line fault location utilizing sparse measurements,” Yuan Liao, University of Kentucky
- “Customized Wavelets for Analysis of Fault Transients in Power Systems,” Ali Abur, Northeastern University
- “Creating the next generation power grid with massively distributed intelligent sensors,” Vijay Jain, Alexander Domijan, Shekhar Bhansali, University of South Florida
Emerging Frontiers in Research and Innovation

**FY 2007**
- Auto-Reconfigurable Engineered Systems
- Cellular and Biomolecular Engineering

**FY 2008**
- Cognitive Optimization
- Resilient and Sustainable Infrastructures

**FY 2009**
- Biosensing & Bioactuation
- Hydrocarbon from Biomass

**FY 2010**
- Renewable Energy Storage
- Science in Energy and Environmental Design: Engineering Sustainable Buildings

**FY 2011**
- Engineering New Technologies Based on Multicellular and Inter-kingdom Signaling
- Mind, Machines and Motor Control
Sample EFRI Projects

- “Neuroscience and Neural Networks for Engineering the Future Intelligent Electric Power Grid,” Ganesh Venayagamoorthy, MST
- “A Multi-Scale Design and Control Framework for Dynamically Coupled Sustainable and Resilient Infrastructures, with application to vehicle-to-grid integration,” Jeffrey Stein, University of Michigan
- $2M awards for 4 years
Industry/University Cooperative Research Center (I/UCRC) Program

- Promotes long-term partnerships among industry, academe, and government
- Centers are catalyzed by a small investment from NSF and are primarily supported by industry center members during their development and evolution
- ~$9M for 2-8 full center awards ($55-80K/year for up to 5 years) and 4-12 planning grant awards ($10K for 1 year)
- Approximately 60 centers currently NSF funded
Power Related I/UCRCs

- Power Systems Engineering Research Center (PSERC)
  - Originally funded in 1996, now in Phase III
  - 13 partner universities, led by Arizona State University

- Grid-Connected Advanced Power Electronic Systems (GRAPES)
  - Funded in 2009
  - University of Arkansas and University of South Carolina

Engineering Research Centers

Key Features of an ERC

- Transformational Engineered Systems Vision
- Systems-Motivated Strategic Research Plan
  - Engineered systems, Enabling technology, Fundamental research
- Inter-Disciplinary Research Program
- University and Pre-College Education Programs
- Industrial Collaboration

Funding for up to 10 years

- $4M per year
- Rigorous post-award oversight and annual peer review
- 2 year competition cycle

For FY11, 2-6 awards (pending funding), possible DOE co-funding
NSF’s FY 2011 Engineering Research Centers

Note: All centers are multi-university partnerships; university shown is lead institution.
Future Renewable Electric Energy Delivery and Management (FREEDM) System Engineering Research Center (ERC)

- "Energy Internet" concept to enable every citizen to participate in energy production, conservation, and utilization.
- Develop plug-and-play infrastructure to enable the use of distributed renewable energy resources.
In Summary

- Many programs in various divisions and directorates at NSF with funding for energy related research
- Engineering and Math & Physical Sciences Energy Working Group recently formed to more closely coordinate activities
  - Co-chaired by George Maracas, ENG, and Linda Sapochak, MPS