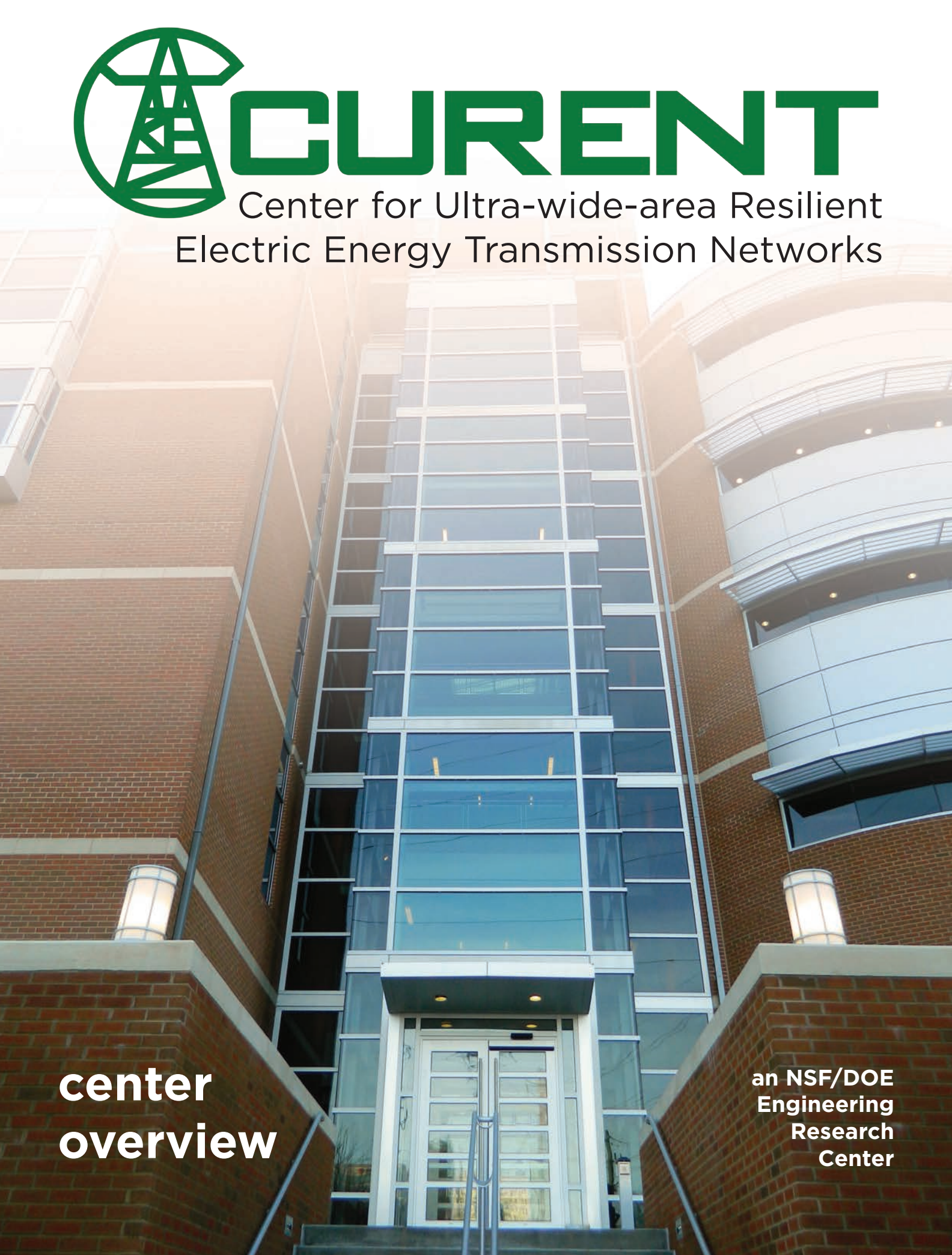
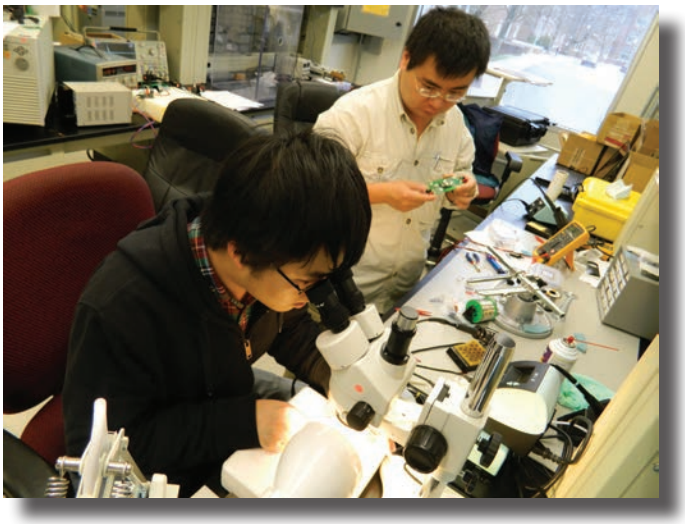
CURENT

Center for Ultra-wide-area Resilient Electric Energy Transmission Networks



center overview

an NSF/DOE Engineering Research Center



CURENT is led by:

THE UNIVERSITY of TENNESSEE KNOXVILLE

with partner schools at:

Northeastern

Rensselaer

TUSKEGEE

CURENT is funded by:

NSF

DEPARTMENT OF ENERGY

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Center overview

Table of Contents

additional information about CURENT can be found at our website:

curent.utk.edu

The CURENT vision and

CURENT, *n.* an Engineering Research Center jointly funded by the National Science Foundation & the U.S. Department of Energy on the University of Tennessee campus: *designing the nation's future electric power transmission system for greater efficiency, higher reliability, lower cost, and better accommodation of renewable sources.* For partner institutions, see also: Northeastern University, Rensselaer Polytechnic Institute, Tuskegee University.

- A nation-wide or continent-wide transmission grid that is fully monitored and dynamically controlled in real-time for high efficiency, high reliability, low cost, better accommodation of renewable energy sources, full utilization of energy storage, and accommodation of responsive load.
- A new generation of electric power and energy systems engineering leaders with global perspectives and diverse backgrounds.

challenges

Perhaps the most important technical challenge facing the electric utility industry over the next several decades is how to address societal energy needs without heavy reliance on fossil fuels.

Less appreciated in this discussion is the critical role that the electric power system transmission infrastructure must play in any viable solution. Most economic renewable resources are located far from population centers or have characteristics that make operation on a local basis difficult, e.g., daily cycles that correlate poorly with local demand. Moreover, one of the potentially most effective ways to reduce our societal carbon footprint is to shift transportation load to the power grid through plug-in hybrid or all-electric vehicles. This, along with the retirement of coal-fired generation plants, requires development of new large-scale generation capacity.

While recently there has been a focus at the consumer level for greater control of demand with approaches such as smart metering, the core challenge facing operation of an extremely large, complex electric network with tens of thousands of transmission lines, buses, and potentially millions of control points remains unaddressed.

Fundamental breakthroughs are needed to control interconnection-wide dynamics and manage resources across vast geographical distances, widely varying timescales, and diverse production sizes.

This is the challenge addressed by the Engineering Research Center (ERC) for Ultra-wide Area Resilient Electric Energy Transmission Networks (CURENT).

industry & innovation

The CURENT Industry and Innovation program's goal is to create a culture that links engineering research to technological innovation through sustained partnerships with industry / practitioner organizations to stimulate technology transfer of ERC research into commercially viable products.

These technology transfer activities offer unique opportunities to form start-up companies by leveraging industry and ERC expertise. Partner schools Rensselaer Poytechnic Institute (RPI), Northeastern University (NEU), and Tuskegee University (TU) are all highly regarded research universities with strong industry support, and some are enhanced by their involvements in past and current ERCs. The ERC team members all have had direct collaboration experience with industry, and many of them have patents.

Through the Industry and Innovation program, the Center will:

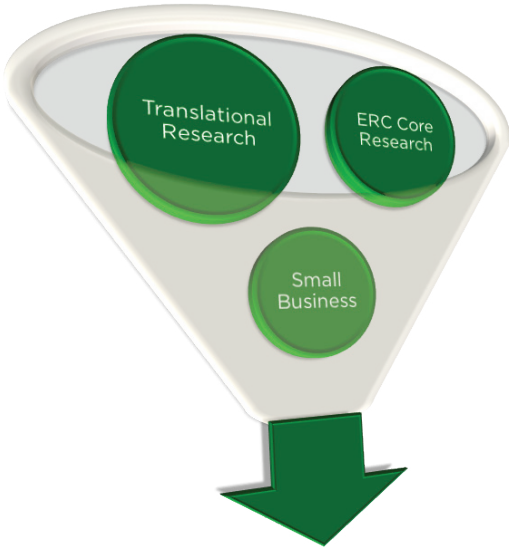
- Involve students in industry collaboration and innovation processes
- Form long-term partnerships with a variety of organizations
- Leverage industry and NSF/DOE support to address major challenges facing the electricity industry
- Equip students with the skills needed to be leaders at a national and global level
- Cultivate collaboration among researchers in academia and industry

Through the collaborative industry model, members can leverage resources while engaging in cutting-edge research and development. Members will provide advice on strategic research plans, IP protection, and research direction. To facilitate the transfer of ideas to commercialization and accelerate the IP process, an Intellectual Property Protection Fund (IPPF) has been established.

Recognizing that industry engagement is critical to the Center's success, multiple avenues are in place to connect the ERC with industry members including:

- Annual Industry Conference
- Short courses and seminars
- Workshops
- Industry residence program
- Student internships
- Web- based portal
- Strategic planning and technology road mapping
- Industrial Advisory Board
- Student Fellowships and Mentoring

To meet the varying needs of diverse industry partners, CURENT has a tiered membership structure that includes Principal, Full, and Associate levels. Principal and full members are companies and other organizations with direct interests in the Center's core research and ERC developed technologies. Associated members include those organizations that support the ERC through donated equipment, components, software, and services that are aligned with the Center's mission. All CURENT industry consortium members have access to the Center's state-of-the-art facilities, personnel, students, and research results.



CURENT Membership Benefits

	principal	full	associate
Access to ERC non-proprietary information	✓	✓	✓
Free or discounted seminars, workshops, conferences, & short courses	✓	✓	✓
Industry resident program	✓	✓	✓
Access to students & faculty	✓	✓	✓
Seat on Industry Advisory Board	✓	✓	
IPPF Member	**automatic**	**optional**	
Non-exclusive royalty-free IP rights for internal use	✓	**IPPF**	
Option for commercial license	**1st**	**2nd**	
Focused Research	✓		
	> $50K	**$10K ($15K)**	**$10K in-kind**

research

CURENT research is a systems-level approach to address the challenges of renewable integration into the large and complex power grid. This problem requires a multi-disciplinary Center approach in order to: (1) have a sufficiently large and diverse team of researchers to address the various research challenges; (2) interact closely with industry to understand practical systems issues; and (3) create the innovative culture needed to transform the legacy system.

The Center identifies the following specific goals as performance indicators for the CURENT system:

- reduce the rate of major power blackouts by 80%;
- increase transmission capacity utilization by 30%;
- allow renewable resource penetration of 50% or greater, without impacting reliability
- realize wide-area control of responsive loads
- achieve near nation-wide grid situational awareness at all control centers.

To realize these goals, we have laid out several research milestones for the first five years, including establishing:

- a high fidelity model of the CURENT system represented by the testbeds with a variety of future operating scenarios
- new high resolution measurement technologies both for synchronized measurements and other sensing technologies
- a control and information structure, which is less hierarchical and allows a decoupling of control design to facilitate renewable integration and demand response
- a systems methodology to take advantage of advancements in wide-area measurement and communication for coordinated action on a continental ultra-wide scale
- use of high performance computing to realize large-scale and faster-than-real-time simulation for predictive control coupled with new visualization tools
- new transmission system architectures that can more fully utilize system capacity
- effective strategies for the use of utility-scale storage
- approaches to mitigate cybersecurity threats to grid operation
- counter-response measures to prevent cascading outages using wide-area measurements
- market structures and incentives to ensure optimal pricing, adequate investment in the transmission network, more rapid adoption of renewable technologies, and a fair sharing of social benefits of the transformed infrastructure.

thrusts

The CURENT research program is organized around the four key areas essential to the CURENT vision of wide-area coordinated control of the transmission grid. These four areas, together with the System Testbeds, constitute the five research thrusts for the CURENT research program.

monitoring

develops the fundamental knowledge and enabling technologies for wide-area system information collection, processing and interpretation, and situational awareness. In the Fundamental Knowledge plane, this thrust covers Estimation & Prediction, Wide-area Measurements, and Situational Awareness & Visualization.

modeling

develops the system and component models and modeling methodology for analysis, situational awareness, and wide-area control. This thrust covers Modeling Methodology, Economics & Social Impact and High Performance Simulation.

control

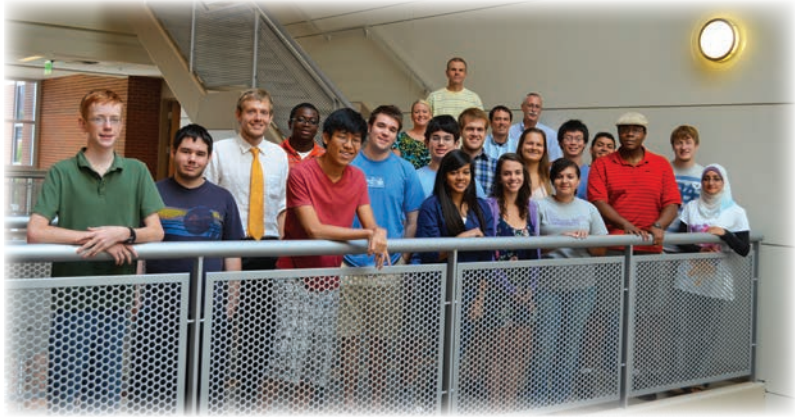
develops system theory and architecture for wide area coordinated control, as well as studies the technologies essential for the control implementation. This thrust covers Control Architecture and Market Structures; Communication & Cyber-security.

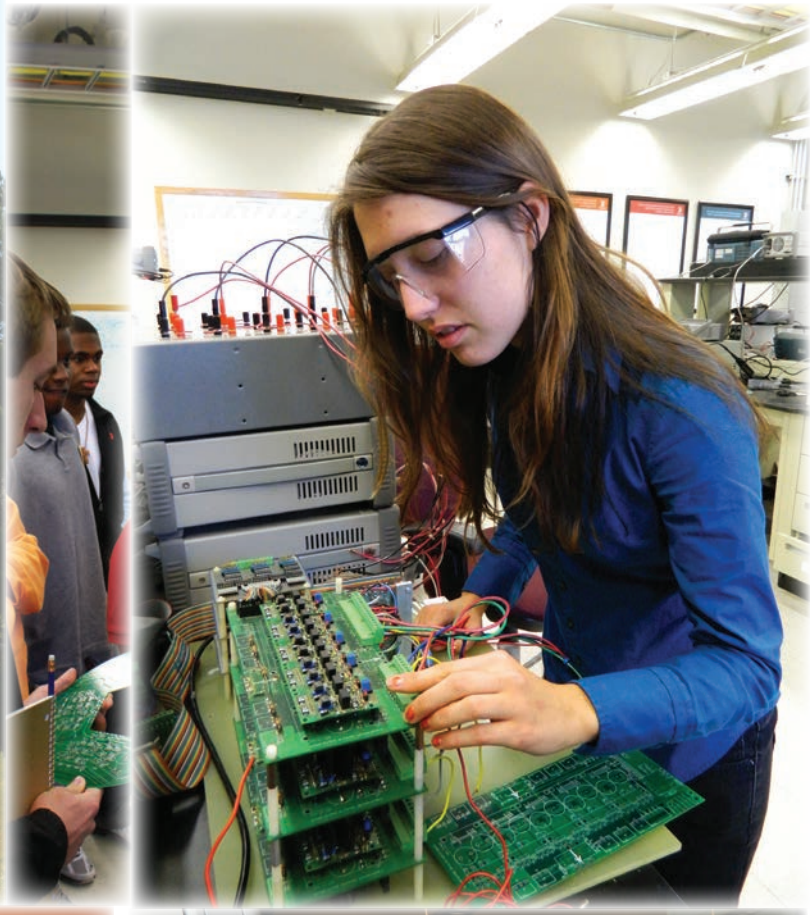
actuation

studies grid architecture and develops actuation technologies suitable for wide-area control. This thrust covers Transmission Network Architecture and Actuators & Control.

systems testbed

this is CURENT's Engineered Systems thrust. Two testbeds are being developed: (1) Large-scale System Testbed (LTB), and (2) Hardware Testbed (HTB). The functions of these testbeds are two-fold: to demonstrate and test developed technologies and to drive the research in the other thrusts through system-level requirements and specifications.





education & outreach

The education program supports the center's strategic plan by cultivating students' creativity and innovation. Programs are designed to enhance students' adaptability and to enable them to thrive in a global environment.

The CURENT education team has established the following objectives to enhance students' academic experience:

- Create programs that increase the participation of domestic, women, and underrepresented minority students;
- Design a multi-disciplinary curriculum focused on electrical energy transmission system analysis and problem-solving skills;
- Develop connectivity with industry, partner institutions, and the larger power and energy system community; and
- Introduce pre-college and undergraduate students to the possibility of pursuing careers in engineering.

CURENT offers several programs for both pre-college and university students:

Pre-college Program

- Research Experience for Teachers (RET)
- Young Scholars Program (for high school students)
- Middle and high school summer programs
- Parents' Night
- Lab tours and field trips

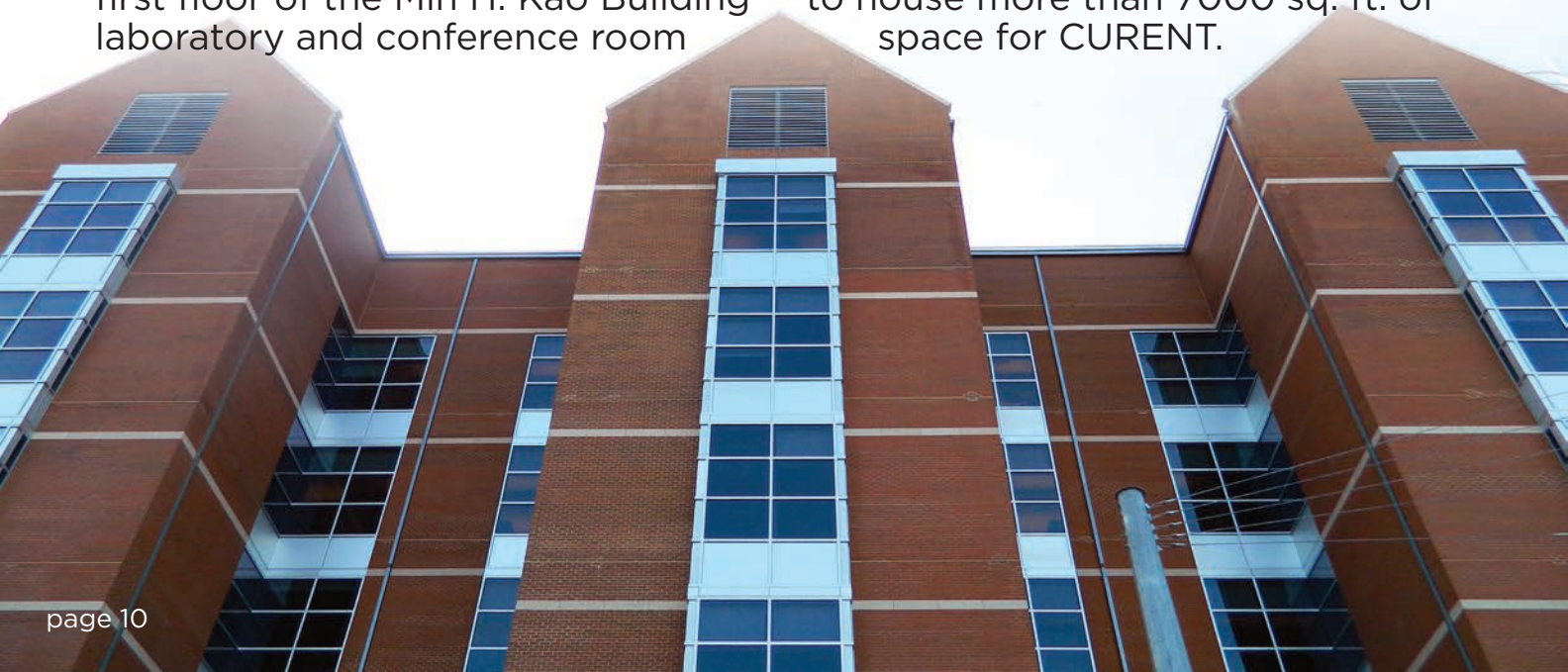
University Program

- Research Experience for Undergraduates (REU)
  - -8-week summer program, or
  - -Academic year program
- Undergraduate concentration
- Senior research projects
- Graduate certificate and fellowships
- Student Leadership Council

facilities

The headquarters of CURENT are located on the University of Tennessee, Knoxville campus in the Min H. Kao Electrical Engineering and Computer Science Building.

This new $37.5 million newly-constructed building opened in January 2012. CURENT occupies more than 16,000 sq. ft. of space to house the CURENT Hardware Testbed, CURENT Large Scale Testbed, CURENT Multimedia and Visualization Center, and FNET monitoring and visualization lab, as well as general power systems and power electronics lab facilities. The University of Tennessee Chancellor's Office has committed $1.4 million to finish the first floor of the Min H. Kao Building to house more than 7000 sq. ft. of laboratory and conference room space for CURENT.



Outside of the UT campus, additional facilities include the following:

UT's Kraken, the world's first academic supercomputer to reach petascale capability (supported by NSF), and ORNL's XT5 Jaguar, formerly the world's fastest supercomputer, are both accessible to ERC faculty.

ORNL's Distributed Energy Communications & Controls (DECC) Laboratory, VERDE (Visualizing Energy Resources Dynamically on the Earth) Laboratory, and $15M Power Electronics and Electric Machinery Research Facility are accessible to ERC faculty. Many faculty have joint appointments at ORNL and as such have access much like regular ORNL staff.

Northeastern

At Northeastern University, the Electric Power and Energy Systems group maintains three laboratories: the Power Systems Lab, the Power Electronics and Motion Control Lab and the Energy Processing Lab conducting researches from LED lighting, solar cells, to electromechanical and systems.

Rensselaer Polytechnic Institute's Distributed Generation and Smart Grid Testbed, supported by NY State Foundation and Power Grid Control Laboratory, will be used in ERC testbed and system research activities.

TUSKEGEE

Tuskegee University has laboratories used to support classes on power systems, energy conversion, and control systems. The Power Systems Lab has motor-generator sets, transformers, relays, transmission line model sets, and three-phase power supplies.

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ELECTRIC ENERGY TRANSMISSION NETWORKS

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