# CURENT

CENTER FOR ULTRA-WIDE-AREA RESILIENT
ELECTRIC ENERGY TRANSMISSION NETWORKS

# Newsletter

*Spring 2014, Issue 2*

a **NSF & DOE**
*Engineering Research Center*

# WELCOME *from* The Director

## Kevin Tomsovic

It is time once again to update you on recent activities in CURENT. This bi-annual publication is one of the ways we inform our members, peers and stakeholders about significant achievements, upcoming events and related activities. As we approach the mid-point of our third year, we want to showcase the value of "Center-type" research - a research model where we bring a diverse group of researchers, students and industry leaders together to focus on comprehensively addressing a challenging problem. A key objective this year is to demonstrate closed-loop wide area controls for voltage and frequency. We will have several demonstrations of the developed concepts on our large scale test-bed and hardware test-bed at this year's Industry Meeting and Site Visit (don't forget to mark your calendar for **May 13-15th**!). Some results of the demonstration projects are detailed in this Newsletter.

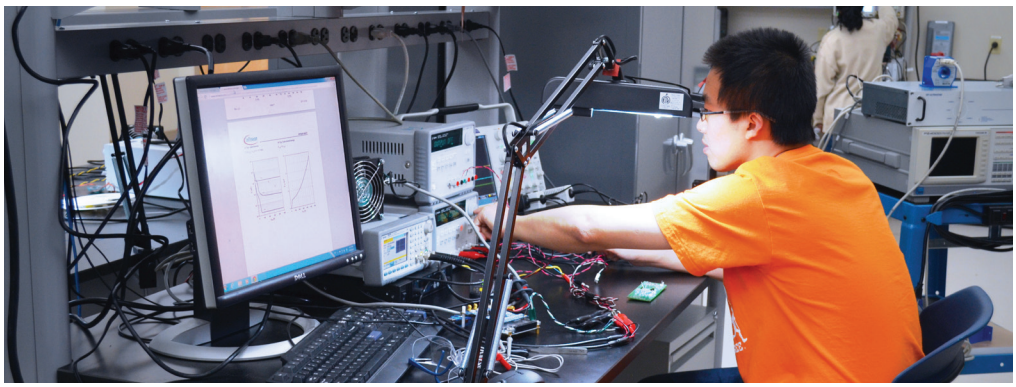
Another way we want to highlight the Center value proposition is to continue to increase engagement with our industry partners. We are approaching this not only through the monthly project reviews but through our co-sponsorship of industry meetings, in particular, the North American SynchroPhasor Initiative (NASPI), which will be held in Knoxville **March 11-12th**. We also invite you to join us for a reception on the evening of **March 11th** in our nearby facilities. Additionally, we are expanding offerings of short courses and training in collaboration with industry. Finally, our progress to date has helped us land additional funding to address Data Architecture and Analytics issues for wide area controls. This is a natural and important extension of our work to date. We will be reporting more on those efforts later this year. As always, let us know if there are ways that we can continue to improve CURENT.

*Best Wishes,*

*Kevin Tomsovic*

# in this issue











## faculty spotlight

**Dr. Daniel Costinett** recently joined CURENT's research group and the University of Tennessee as an Associate Professor. He earned his Ph.D. in Electrical Engineering from the University of Colorado at Boulder in 2013.

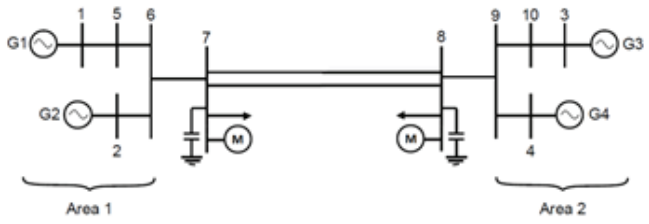
Dr. Costinett's research interests include resonant and soft switching power converter design, high efficiency converters for data centers, energy harvesting, and electric vehicles.

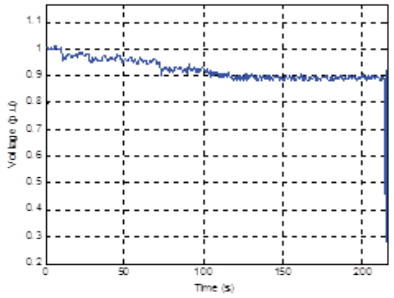
Welcome, Dr. Costinett!

## Hardware Testbed

CURENT has developed a hardware demonstration platform using power electronic converters for demonstrating wide-area voltage and secondary frequency control in its hardware test bed. The test bed uses two power electronic clusters to emulate different parts of a small scale power system. Each of the power electronic clusters consists of several power electronic converters emulating different components in the system. Load is emulated using ZIP+ induction machine models, which includes the dynamic behavior of the induction machine. The sources range from typical synchronous generators to full scale emulation of photovoltaic and wind turbine models. The entire system is controlled using a LabView interface incorporating many of the features found in modern control rooms. The control room also allows for incorporating real-time wide-area measurements and closed loop operation of voltage and frequency to demonstrate techniques developed by other thrusts within the center.

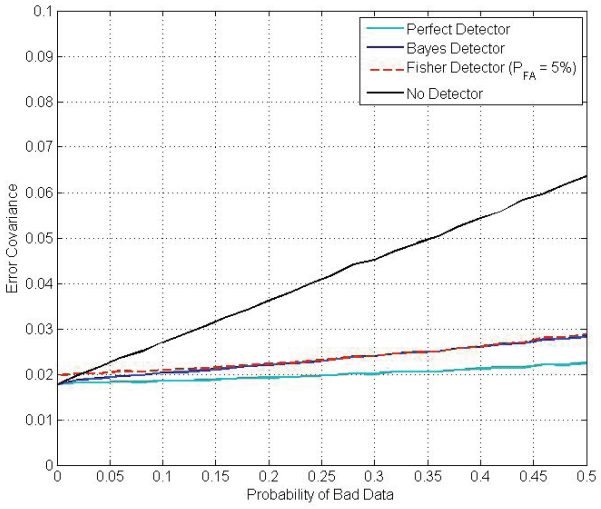
As an example, one of the wide-area closed loop voltage control demonstrations in the hardware test bed is done by emulating the load center and boundary busses in an area and using PMU measurements to predict the voltage stability margin in real time. By knowing the stability margin in real-time, actuators can be controlled before the system reaches instability.




## Robust Dynamic State Estimation Using Wide-area Synchronized Measurements

Accurate dynamic estimation of generator states and, in particular, of its frequency, is essential to efficient control of ultra wide-area electric power grids. Such state estimates can also be used in prevention of cascading failures and dynamic security analysis.




The primary objective of this research is to provide dynamic estimates of generator states that are robust with respect to timing and system parameter inaccuracies and, in addition, can minimize the effects of network perturbations such as transmission delays, corrupted sensor measurements ("bad data") and information packet drops. To achieve this objective we rely on a recently developed robust version of the Kalman filter, which we augment with delay mitigation and bad data detection capabilities.

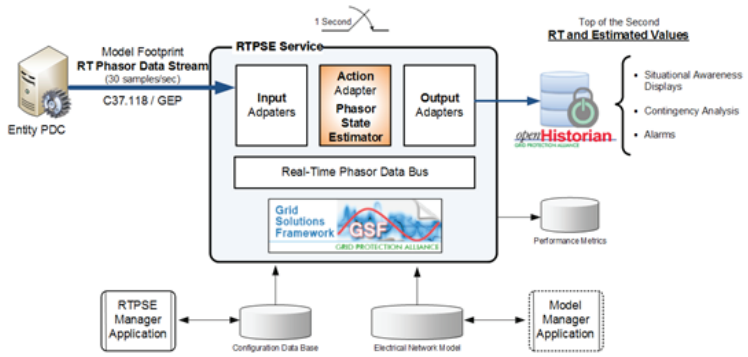
We are also developing compact performance metrics that can predict the quality of our dynamic state estimates in the presence of various network perturbations. Our goal is to use such metrics to evaluate and compare alternatives in sensor deployment, so as to provide guidelines for optimal deployment.

## Phasor-Based State Estimation

Over the last three years, the quantity and quality of synchrophasor measurements made on the U.S. electric grid have dramatically increased. In addition, the performance and robustness of the systems used to collect and manage this high-sample rate, GPS time-stamped data have greatly improved. The number of real-time phasor measurements in some Reliability Coordinator control rooms is now approaching the level needed for full analysis of the electric grid through synchrophasor measurements alone. This full analysis requires a real-time phasor state estimation (RTP-SE) developed in the Modeling and Estimation Thrust, and is an enabling technology for wide-area measurements.

The RTP-SE will be based on synchrophasor measurements; it will be able to cycle at least at a one-second interval; and it will provide unprecedented capability to:

- Calculate "pseudo" PMU measurements at unmeasured buses and lines
- Correlate PMU data across a network, allowing data quality enhancement and filling in missing data
- Enable interface flow calculation even though not all flows are directly measured with PMUs
- Monitor generator (fossil and wind turbine) active and reactive power outputs without implementing a PMU at the generator substation
- High-sampling-rate allows dynamic visibility of disturbances (voltages and power flows), disturbance propagation, frequency response, and oscillations
- Establish real-time models to determine stability margins




In July 2104, Rensselaer Polytechnic Institute submitted a proposal to the NSF SECO project, led by Grid Protection Alliance (GPA). The objective of the proposal is to develop, test, demonstrate and commercialize the RTP-SE. The project team believes that the RTP-SE is necessary, if not critical, to realizing the full value from synchrophasor measurements. Through the capabilities enumerated above, the RTP-SE will provide more complete, higher quality and more reliable synchrophasor data streams for use by control center applications and operators.

The RTP-SE solution will be built as a commercial extension of GPA's Grid Solutions Framework© (GSF). This free, open source library of software is in production use in many control rooms in North America and is the foundational component for GPA's open source product offerings such as the open phasor data concentrator (openPDC). Using this proven, extensible framework simplifies the implementation of the RTP-SE and allows the project to focus effort on the development of the state estimation analytics – or the "Phasor State Estimator Adapter" (PSE-Adapter). Use of the GSF also provides an easy path to utilization and commercialization.

The PSE-Adapter will be developed by RPI based on previous work that was supported by CURENT and on synchrophasor measurements from the Central New York Power System. The adapter will be refined and improved using data from the New England Power System and additional portions of New York State.

The National Science Foundation has informed the project team that the project has been selected for funding, and contract negotiations are underway.

## education

### CURENT Students and Faculty Visit China

During the 2013 winter break, most University of Tennessee students were headed home for the holidays. A handful of future electrical engineers had other plans, though. UT undergraduates Jessica Boles, Summer Church, Lily Hoang, and Matt Lambert joined Ph.D. student Micah Till and faculty members Chien-fei Chen and Daniel Costinett from CURENT to embark on a visit to three cities in China. The trip was organized so that students could meet with Chinese universities focusing on the study of electric power. These universities, Tsinghua University, North China Electric Power University (NCEPU) and South East University (SEU), welcomed the CURENT students and faculty as the first such group from the United States to visit their campuses.

The group set out on a 12-day trip following UT's final exams and were soon immersed in power and energy research laboratories, power utility companies and Chinese culture. CURENT offered this trip as part of its mission to expose students to global perspectives of engineering and to provide students the opportunity for cultural exchange, according to Dr. Chen, the center's Co-Director of Education & Diversity Programs.

The expedition began in China's capital city, Beijing, with a visit to Tsinghua University. While at Tsinghua, the CURENT visitors were given a tour, led by local students and faculty, of the laboratories for power electronics and power systems. The group was also able to meet with the associate head of electrical engineering, Dr. Xin Jie Yu and 10 graduate and undergraduate students to discuss and compare the course structure, student life and research philosophy to those of UT, Knoxville. In addition, Dr. Zhengming Zhao's research group gave a presentation covering their research directions and focus in power electronics, with particular emphasis on future applications of photovoltaics and electric vehicles.

During the visit, CURENT student Summer Church was able to exchange research ideas with Tsinghua students.

"I met a student at Tsinghua who was working on a 'Smart Building' project, the same type of research I have assisted with at UT," said Church, a freshman in electrical engineering. "It was exciting to see how universities are aspiring to reach identical goals within engineering, even on the other side of the world."

The group next visited NCEPU, an institution whose curriculum and research focuses heavily on the areas of power systems, power electronics and renewable energy technologies, which align with CURENT's research focus. The CURENT group toured NCEPU's State Key Laboratory of Alternative Electrical Power Systems with Renewable Energy Sources. One of the highlights was the intercultural communication between Chinese and U.S. students.

"Conversations with students about everyday subjects such as leisure activities, research, travel, religion, and politics not only fostered intercultural friendships but also gave us a better insight into Chinese life both inside and outside of the academic setting," said Jessica Boles, a junior studying electrical engineering.

The last academic visit was to Southeast University in Nanjing. The visit was hosted by university vice president Dr. Hu Minqian and associate head Dr. Xiaobou Dou of the Department of Electrical Engineering. The CURENT group was introduced to a variety of power systems and power electronic research labs.

CURENT's students were also able to engage in further cultural exchange by spending significant time with the SEU professors and their students.

During the group's trek through China, Dr. Daniel Costinett, an Assistant Professor in CURENT, gave a presentation to faculty and students at each of the three universities. The seminars covered the wide range of applications in power systems and electronics that the center investigates. Dr. Costinett also highlighted his research topics, including the design of electric vehicle technologies and high-efficiency power supplies.

Besides the academic visits, the group also toured the largest utility provider in China, State Grid Corporation in Beijing, and the Jiangsu Electric Power Company in Nanjing, which provides power to many of the 78 million people in the Jiangsu Province. The CURENT group was able to visualize the real time power grid operation and learn about current development of power grid projects in China. The group also visited the Great Wall, Tiananmen Square, and the Forbidden City in Beijing, and experienced the beautiful Chinese Yu Garden and the Lujiazui District Skyline in Shanghai.

Overall, CURENT students were impressed by these universities' facilities, research scopes, and the Chinese government's commitment to solving engineering challenges.

## Student News

### Interning at Dominion

Two students in Dr. Yilu Liu's research group, Jerrel Cullis and Micah Till, recently interned at Dominion Virginia Power's RTDS Lab in Richmond, Va. While there, they created a real-time synchrophasor simulator to act as a platform for operator training and PMU research.

"Dominion allowed us to fully own our project while providing the oversight necessary for the success of our work there," said Till. A paper over the project is currently under review for publication.

As part of their principal membership, Dominion identified a project that aligns with the Center vision of wide-area monitoring, modeling and control of the grid while also providing value to their company. Matthew Gardner from Dominion expressed his appreciation for the excellent work performed this past summer.

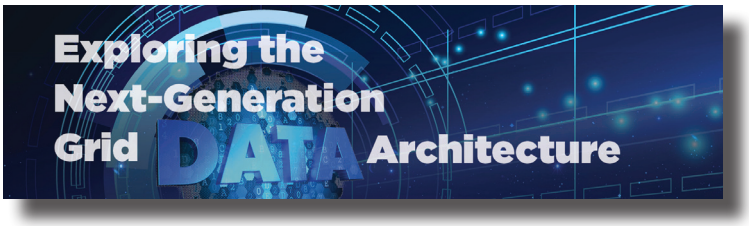
"Micah and Jerel helped Dominion enhance our studies and simulation capabilities by building a novel RTDS-based real-time synchrophasor-driven operator training simulator. This project was completed in record time and set the bar higher for Dominion and the industry. We look forward to working with these students and others from CURENT in the future."

**Congratulations** to the recent graduates within the center. The following students completed their studies at CURENT in Fall 2013:

- **Hao Huang**, Ph.D; *Intern,* EnerNex Corporation
- **Brandon Johnson**, M.S.; *Post-Masters Research Associate,* ORNL
- **Mert Korkali**, Ph.D.; *Post-Doctoral Research Associate,* University of Vermont
- **Fan Xu**, Ph.D.; *R&D Engineer,* ANSYS, Inc.
- **Zhuxian Xu**, Ph.D.; *Engineer,* Ford Motor Company

## industry updates

### Recent Awards




CURENT was awarded $1M to explore the next generation of data architecture needed for the power grid of the future. The purpose of this joint National Science Foundation and Department of Energy project is to foster open collaboration among industry, academia and national laboratories to identify issues, establish requirements, and propose a data architecture that will ultimately enable the use of new data driven computational methods to simulate, monitor, analyze, and/or control the grid's behavior. These necessary new computation methods will enable, for example, faster-than-real-time dynamic simulations that can provide more proactive decision support for grid operators as well as advanced capabilities such as wide-area closed loop voltage control, adaptive protection, and automated switching.

Additionally, data analysis methods will be investigated to enable full use of the recent and projected increase in grid operational data. Along with the partner institutions with CURENT, experts from Washington State University, University of Illinois, and Texas A&M will be involved in the data analytics research.

### NSF SECO/SBIR Award

Congratulations to Dr. Joe Chow, a Thrust Leader in CURENT, and Grid Protection Alliance, who were recently awarded Small Business Innovation Research program funding for the development, testing, and commercialization of a Real-time Phasor State Estimation project.

### *Welcome to Our Newest Industry Partners!*

New York Power Authority

GRID PROTECTION ALLIANCE

## upcoming events

**March 11-12: NASPI Work Group Meetings; Knoxville, TN**

**more info:**

This meeting will feature user success stories on how using synchrophasor technology has increased grid reliability & efficiency, enhanced staff and asset effectiveness, availability and productivity, and made everyday work easier and better.

CURENT will also host a cocktail reception & lab tour on the evening of March 11th, showcasing our hardware and large scale testbeds. Come join us!

**May 12-16: Industry Conference & Site Visit; Knoxville, TN**

**more info:**

CURENT invites our industry partners and other interested parties to attend the Industry Conference. This will be an opportunity to showcase the research that CURENT has performed during its third year and discuss plans for future progress.

More information will be available soon at:
curent.utk.edu/sitevisit2014

## CURENT's *Seminar Series*

**Upcoming Seminars:**

Feb. 28 - Joe Gipson, Cisco Systems Inc.

Mar. 28 - Dr. Fred Wang, CURENT

**Past Seminars:**

Jan. 31 - Dr. Kai Sun, UT-Knoxville

Nov. 22 - Vikas Singhvi, EPRI

Nov. 1 - Dr. Leon Tolbert, UT-Knoxville

Sept. 27 - Dr. Aleksandar Dimitrovski, ORNL

Note: past seminars are available on our website at:
curent.utk.edu/seminar

## Synchrophasor Short Course

- 8:00-4:00 p.m.; April 8, 2014
- Knoxville, TN
- Cost: $50 (members); $250 (non-members)

More information will be available soon at:
curent.utk.edu/shortcourse

## *contact us*

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