CURENT

Fall Newsletter

August 2013 | Issue 1

universities

THE UNIVERSITY of TENNESSEE KNOXVILLE

Northeastern

Rensselaer

TUSKEGEE

industry

ABB

ALSTOM

Dominion

EPRI ELECTRIC POWER RESEARCH INSTITUTE

ISO new england

NRECA

ISO

OAK RIDGE National Laboratory

pjm

TVA

VACON

Director's Welcome

It gives me great pleasure to introduce our inaugural CURENT newsletter. This bi-annual publication will inform our members, peers and other stakeholders about significant achievements, upcoming events and other related activities. We are excited about the accomplishments we have made in getting the Center operational and are ready to take on the challenges moving forward. We have already seen anticipated changes in the industry, such as the substantial installation of renewable generation and the rapid switch to natural gas coming on line due to inexpensive shale gas. These changes support our belief in the need for a flexible transmission system that is reliable in operation despite the uncertainties it must face. As we begin our third year of operation, we are ready to take a big step towards our vision of wide area situational awareness and wide area controls during this transformational time for the industry. With the support of the NSF, DOE and our strong membership base, I believe we have the tools to be successful. Please keep reading to find out more about the progress of the Center and send us your feedback so we can continue to improve our communications and strategic planning.

Best Wishes,

Kevin Tomsovic

Upgrades and additions

Construction of an additonal 7,275 square feet of lab, research, and meeting space has recently been finished at the lead institute, UT, Knoxville.

In all, four new labs and one new conference room were added for CURENT's use. This new space establishes the center as a major research hub on UT's campus, and provides enough room to accomodate over 60 graduate-level students.

Read more about what we've added on page 6.

A special welcome to our newest Industry Partners!

Tektronix®

Mehta Tech, Inc.

CERTES NETWORKS

SENETAS trusted to secure critical information

SCOUT CYBER SECURITY

GLOBALPOWER ELECTRONICS

Advancements in Modular Multilevel Coverters Facilitate Deployment of Off-Shore Wind

The Modular Multilevel Converter (MMC) is a preferred topology for HVDC transmission, especially multi-terminal HVDC grids. DC grids can potentially be more cost effective than AC grids, especially for offshore wind farms, where DC cables are much cheaper. DC grids can also provided stability benefits when used to connect with AC grids. One drawback of the MMC topology is the requirement for larger capacitors in each module and inductors in each arm. These passive components constitute a significant portion of the overall MMC cost, and therefore should be minimized.

Researchers in the power electronics research group at UTK have been working to characterize the minimum arm inductance and module capacitance required to meet the demands of HVDC transmission, during normal operation as well as fault conditions. Theoretical relationships have been derived for the first time and are currently being verified with a scaled-down prototype built in the CURENT lab.

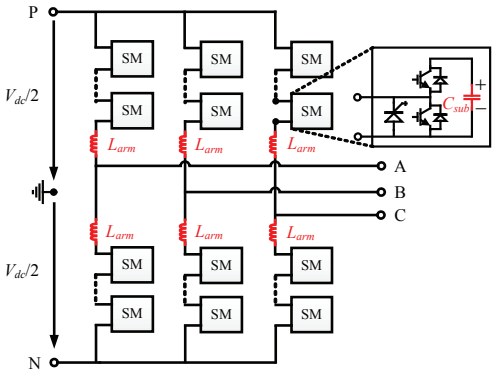


Fig. 1 MMC topology with arm inductors and submodules capacitors highlighted

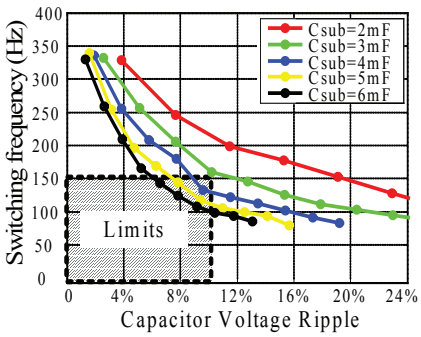


Fig. 2 Submodule capacitor selection principle

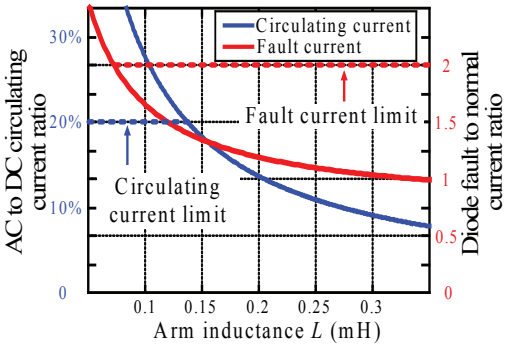
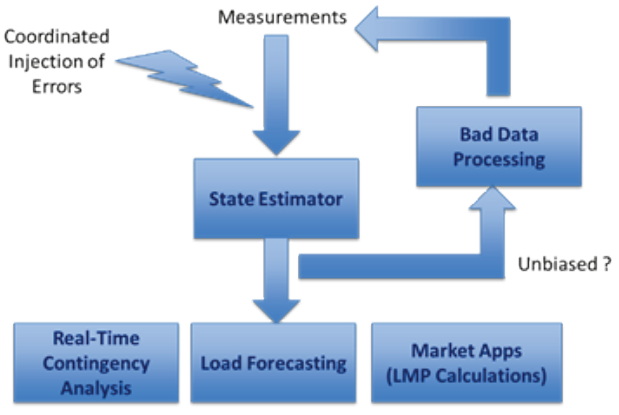


Fig. 3 Arm inductor selection principle

Identifying Vulnerability Against Cyber Attack on State Estimators

Power system state estimation is one of the key control center applications since its results are used by other functions necessary for operating the system and power markets. Hence, having a state estimator that is robust against intentional errors (or so called cyber-attacks), as well as other types of errors, is critical. Estimated system states, namely bus voltage magnitudes and angles, are used to calculate the "estimated branch flows" in the system. These estimated branch flows are used for static security assessment as well as for determining loading and congestion levels which in turn will impact energy pricing. Therefore, any type of manipulation of these estimated flows due to cyber-attacks will have to be avoided.

It has long been known that by manipulating a finite number of measurements, a hacker could bias the results of state estimation without being detected. These measurements are known as the "critical measurements" in state estimation. In this work we investigate a certain type of cyber-attack that can be carried out by manipulating a strategically selected subset of critical measurements. We illustrate the risks associated with having such critical measurements and how to identify these types of "vulnerable measurements" so that they can be transformed. This will require investments in new meters which need to be strategically placed in order to transform the existing critical measurements, making them no longer vulnerable to cyber-attacks.



A New Approach to Calculate Votage Stability Margin

RPI has recently been studying a new method for computing steady-state voltage stability margins that will address singularities in power flow calculations that are common at maximum loading. Using a power flow method with a new bus type, the group will be able to ensure that current operating conditions are voltage stable.

The new bus type, called an AQ bus, specifies both the angle (A) and the reactive power (Q), and will be used to replace a conventional PQ-type load bus. The major advantage of this unique approach is that the singularity at the maximum loading condition is eliminated, and the voltage stability margin can be calculated reliably and quickly.

In addition, the AQ-bus approach has readily applicable conventional power flow algorithms such as generator reactive power limits and tap-changing transformers. This is because the only difference between the AQ approach and a regular power flow is the bus type.

In the lab, the method has been developed for a simple two-bus system and applied to the Klein-Rogers-Kundur 2-area system with a generator variable limit. Multiple loads and generators were then added to the method, and it was tested on the Northeast Power Coordinating Council's (NPCC) 48 machine system for analysis.

The research group at RPI envisions that the AQ-bus method has strong potential for both real-time and offline voltage stability analysis.

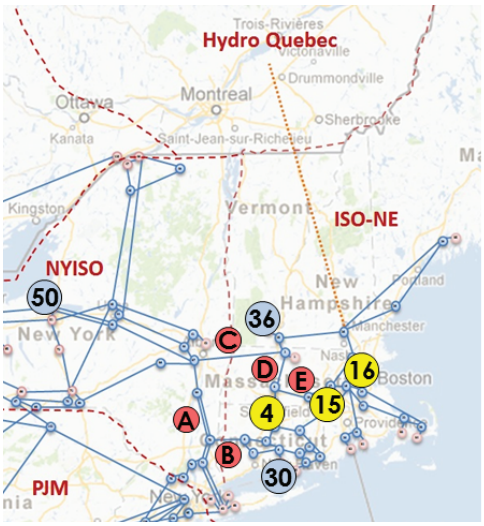


Fig. 1 NPCC 48-machine system with multiple loads, generators, and line outage contingencies

Generator schedule for 48-machine system

Generator Bus #	Bus Type	β_k
50	AV (swing)	-
30	PV	0.10
36	PV	0.80

Load schedule for 48-machine system

Load Bus #	Bus Type	α_ℓ	Power Factor
16	AQ	-	0.95 lag
4	PQ	0.50	0.95 lag
15	PQ	0.25	0.95 lag

Contingency list for 48-machine system

#	Line Outage	Power Flow
A	73–74	72 MW
B	8–73	97 MW
C	2–37	53 MW
D	3–2	295 MW
E	3–18	50 MW

Game Theory Being Used for Distributed Control of the Grid

The quality of power delivered to customers is a measure of the reliability of a power grid. Complex interactions exist between the various power system components, where the overall objective is to ensure that power is delivered within acceptable voltage and frequency levels. Tuskegee University is working towards a novel concept based on a Game-Theoretical approach for distributed control of the power system. Researchers have developed an algorithm that analyzes complex interactions between system control elements such as generators, tap-changing transformers and compensators for optimization of system parameters. This ensures a controlled reactive power flow and a uniform voltage profile across all buses.

The research group successfully implemented localized control using an IEEE 6-bus system, and is now working with the IEEE New England 39-bus system that has been divided into four independent areas to implement distributed control. The future work includes the integration of renewable energy sources to serve as compensators to address voltage and frequency perturbations in the system. Reactive power requirements from the Game Theory algorithm will set reference levels for reactive power production from the wind turbine and the PV generations being integrated into the system to assist in the regulation of the power system to obtain the acceptable frequency and voltage level requirements.

CURENT Holds Second Annual Site Visit and Industry Conference

The research group and staff at CURENT recently wrapped up their second annual Site Visit and Industry Conference. The three day event overlapped two major meetings in the center, and brought together nearly 200 faculty, students, and industry representatives from across the country.

The first day offered an opportunity for CURENT to showcase its research portfolio to industry partners and companies looking for potential collaborations. Invited speakers with an expertise in power systems and power electronics presented on CURENT-related research topics.

The speakers included Dr. James Thorp from Virginia Tech, Dejan Sobajic representing the NY-ISO, Jay Giri from Alstom and Jim Lyons from Capricorn. Following the industry talk, students in the center had an opportunity to present their ongoing projects. In addition, industry members recognized CURENT students Liu Yang, Liuxi Zhang, and Scott Ghiocel with Most Outstanding Presentation awards.

The second leg of the event brought representatives from the National Science Foundation and Department of Energy to campus to review the overall progress of the center. NSF and DOE personnel met with UT administrators, CURENT's leadership team, industry members, and students in the center to discuss benchmarks and future growth.

Partner school faculty and students from Northeastern University, Rensselaer Polytechnic Institute, and Tuskegee University were also in attendance to highlight their related research. Students from all four universities participated in research presentations, presented posters during the lab tour segment, and got a chance to meet and network at a student awards banquet.

CURENT is working with the NSF to finalize dates for the 2014 Site Visit now, and that information will be posted once it becomes available.

Upcoming Meetings & Conferences with CURENT

First Thursday of Each Month

Monthly Progress Meetings
via Conference Call

Last Friday of Each Month

Seminar Series
via Conference Call or On Campus

October 24-25, 2013

Strategic Planning Meetings
Rosemont, IL

May 13-16, 2014

Site Visit & Industry Conference
Knoxville, TN

Middle School Girls Take an ADVENTURE IN STEM

Solar houses, microbial leaf prints, and disease modeling games probably aren't on your typical summer camp itinerary. Then again, Adventures in STEM isn't your typical summer camp, either. The program, which is in its second year at CURENT, brought twenty middle school girls from all around the state to the University of Tennessee for a week filled with science, technology, mathematics, and engineering projects.

Students worked with CURENT, the National Institute of Mathematical & Biological Synthesis (NIMBioS), and Tennessee 4-H throughout the week. Each department brought hands-on activities and group projects into the classroom so that the girls could explore a range of STEM-related fields and professions. The girls in the program also had the opportunity to meet and interview engineering, math, and biology researchers and students at UT.

"Youth involved in 4-H learn by doing, and this fit well into the objectives of the program," said Daniel Sarver, an Extension Specialist with 4-H. "The girls learned how living things live together in our complex, yet fascinating, natural world."

The girls took a break during the middle of the week to get some of the "UT Experience" as part of a field trip activity. The day started bright and early at Second Creek, where Dr. Michael McKinney, UT's Director of Environmental Studies, talked to the group about their impact on natural resources. The girls then took a ride on the new "T" campus buses all the way to the Ag Campus, where they explored the UT Gardens, UT's Living Light Solar House, and a tour of the College of Veterinary Medicine's Small and Large Animal Clinics, led by Professor John New. After lunch at the Ag Campus, the group wrapped up their tour with a look inside Dr. Lynne Parker's Distributed Intelligence Lab. At the end of the week, the future scientists put all their notes and experiences to use by making posters and presenting their projects to family, faculty, and staff at an open house session.

The Adventures in STEM summer program is part of CURENT's mission to engage students from an early age in STEM-related fields, especially engineering. This year's participants came primarily from East Tennessee, with a handful of girls from the middle region of the state as well.

"We hope some of the activities this week captured the imagination of these smart girls and inspired them to pursue STEM some day," said Kelly Sturner, the Education and Outreach Coordinator for NIMBioS.

Summer Research at CURENT

5 High School Teachers

13 High School Students

14 Undergraduates

Twenty-five undergraduates, high school students, and teachers participated in CURENT's 2013 summer research programs.

While on campus, the group worked in research labs, seminar halls, and classrooms on a variety of assigned projects. Some worked one-on-one with a CURENT graduate student, while others worked in groups.

Besides performing research in the center, the summer students also attended numerous professional development seminars ranging from resume writing to engineering career options. In addition, the group took in-depth field trips to TVA's Bull Run Fossil Plant, Oak Ridge National Laboratory, and the Electric Power Research Institute.

The students wrapped up their experiences by completing a paper and presentation, and then creating a research poster to showcase at UT's Summer STEM Symposium.

Student Spotlight

Edward Jones has recently been elected as CURENT's Student Leadership Council President. Edward is a Ph.D. student in the center and a Bredesen Center Fellow.

What's CURENTly Going On

Facility Updates (cont.)

The center recently added 7,275 square feet of space on the 1st floor of the Min H. Kao Building.

Hardware Testbed & Grid Emulaton Lab
Used for housing and system-level testing of CURENT's hardware testbed.

Grid Control & Visualization Lab
For remote control & visualization of hardware testbed, video display of monitored, emulated, or simulated grid data. Also used for training and high performance computing.

Conference Room
Used for meetings & voice/video conferencing.

Power Electronics Lab
Used to construct, characterize, and/or test power electronic components, modules, and converters.

High Power Electronics Lab
With high power testing room and motor/dynamometer room.

INDUSTRY

Take a look at recent activity and upcoming plans for our industry relations

CURENT *Seminar Series* Begins!

The center invites industry leaders and academic experts to participate in our seminar series at UT, Knoxville on the last Friday of each month.

Seminars begin at **12:20pm**.

Upcoming Seminars:

- Sept. 27, 2013 - Aleksandar Dimitrovski, ORNL
- Nov. 1, 2013 - Leon Tolbert, UT
- November 22, 2013 - Vikas Singhvi, EPRI

Seminars are available for live streaming, and can be downloaded for future viewing at **curent.utk.edu/seminar**

COMING SOON

Short Courses @ CURENT

The center will soon be offering training and development **short courses** for industry professionals. The courses will be available onsite at UT and via webcast.

Potential topics will include:

- Intro to Energy Management Systems
- Synchrophasors
- Protection & Control
- Power Electronics
- MATLAB for Power Engineers

Contact Brad Trento @ ***865.974.4799*** *with other topic ideas*

THE UNIVERSITY of TENNESSEE KNOXVILLE

CURENT
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