

**Fiscal Year 2011
Impact Report**



at ILLINOIS INSTITUTE OF TECHNOLOGY

Robert W. Galvin Center for Electricity Innovation

The Robert W. Galvin Center for Electricity Innovation was officially created in 2011 through the generous contributions of Robert W. Galvin and The Robert W. Galvin Foundation. The mission of the Robert W. Galvin Center for Electricity Innovation is to pursue groundbreaking work in the generation, transmission, distribution, management and consumption of electricity.



The center is bringing together researchers, industry, government and innovators to “plug-in” to IIT’s smart microgrid, research laboratories and Technology Park, creating a hub – or sandbox – for new innovations in advanced grid technology.

The center has recently completed its first full year in operation with a number of significant accomplishments that have established its reputation as an international leader in electricity innovation.





State-of-the-Art Facility

In January 2012, the Galvin Center completed and moved into a new, state-of-the-art facility designed to house its Smart Grid, microgrid and energy research, demonstration and education activities.

Located on the 16th floor of the IIT Tower, the 16,000-square-foot center contains offices, exhibition rooms, classrooms and student workrooms, acting as a hands-on experience center for Smart Grid, microgrid and energy technology and education.

The \$3 million project was funded by the State of Illinois, U.S. Department of Energy and IIT.



Mayor Emanuel Visit

Shortly after opening, the new space was visited by Chicago Mayor Rahm Emanuel and ComEd President Anne Pramaggiore for the announcement of a \$1.1 billion electric system infrastructure investment plan that will create more than 2,400 jobs for Chicago.



New Wind Turbines

In 2011, the Galvin Center hosted the ribbon cutting for its 8kW Viryd wind turbine located on the Stuart Soccer Field at IIT. Visible from four major transportation channels (the Dan Ryan Expressway, the CTA's green and red lines, and a Metra commuter rail line) as well as U.S. Cellular Field, the unit is the most visible wind turbine in the city of Chicago and is designed to increase public awareness of the possibility of wind power and continuing innovations in the field of wind energy.

The Galvin Center is also operating an 8kW Viryd turbine located in a lab on IIT's campus. Environmental conditions are gathered from the field turbine on the soccer field and then simulated on the lab turbine, located in Siegel Hall.

Also last summer the Galvin Center cut the ribbon on IIT's 1.5MW wind turbine at an Invenergy wind farm in LaSalle County, Illinois. The utility-grade turbine is being utilized for cutting-edge wind energy reliability studies.



Conferences and Symposium

ISGT Conference

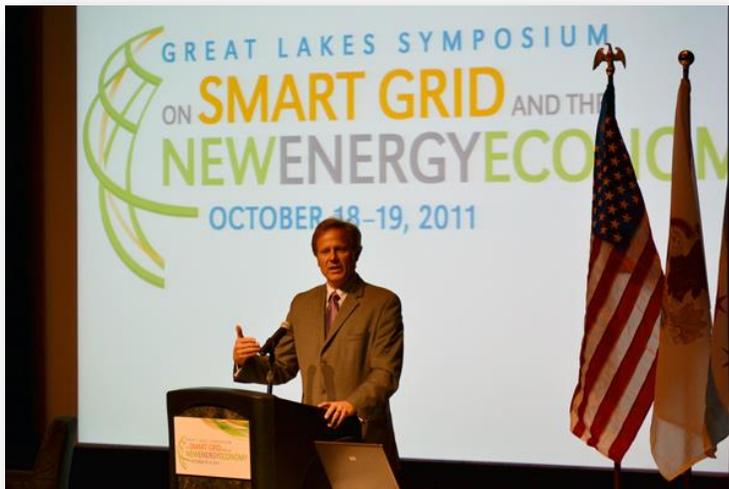
On January 16-20, 2012, Galvin Center Director Dr. Mohammad Shahidehpour chaired the third IEEE PES Conference on Innovative Smart Grid Technologies (ISGT) in Washington D.C.

The conference attracted thousands of attendees from throughout the world and served as a premier forum for discussion of state-of-the-art innovations in smart grid technologies.



Great Lakes Symposium

On October 18-19, 2011 the Galvin Center held the first annual Great Lakes Symposium on Smart Grid and the New Energy Economy. This one-of-a-kind event broke new ground in Smart Grid design and development, attracting more than 400 attendees to IIT's campus for the two-day conference.

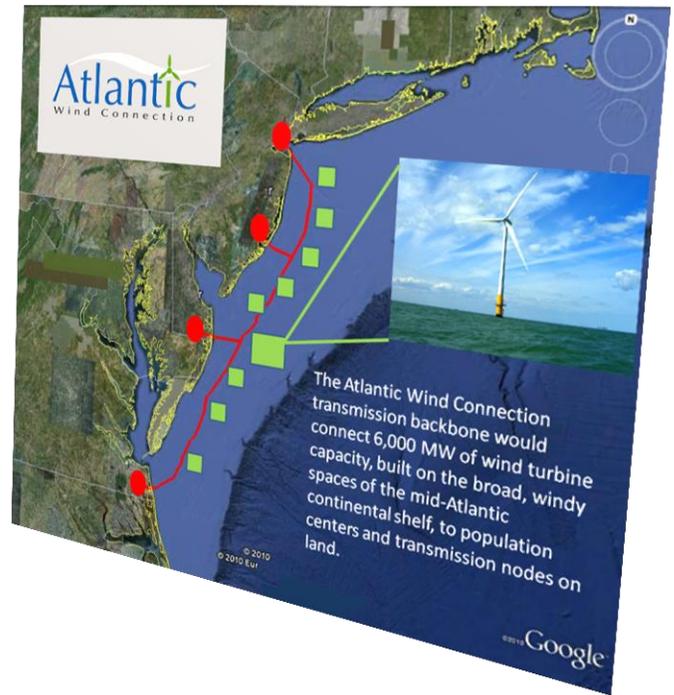


The event showcased Smart Grid best practices from around the country along with innovative technologies and ideas that are spurring innovation, growing economies, reducing emissions and empowering consumers to conserve and save. Participants engaged thought leaders on key policy questions, identified investment and job creation opportunities, and learned about projects already underway.

The conference featured a number of leaders from across the energy industry, including: Rahm Emanuel, Mayor, City of Chicago; Michael Niggli, President and CEO, San Diego Gas & Electric; Anne Pramaggiore, President and COO, ComEd; Teri Ivaniszyn, Senior Director of Corporate Excellence, Florida Power & Light; Doug Scott, Chairman, Illinois Commerce Commission; Ellen Alberding, President, Joyce Foundation; Scott Lang, President and CEO, Silver Spring Networks; Luke Clemente, General Manager of Metering & Sensing Systems, GE Energy; Philip Moeller, Commissioner, Federal Energy Regulatory Commission; David Kolata, Executive Director, Citizens Utility Board; Matthew Summy, President, Illinois Science and Technology Coalition; and Miriam Horn, Director, Smart Grid Initiative, Environmental Defense Fund.

Wind Consortium Conference

On July 20, 2011, the Galvin Center hosted the annual meeting of the University-Industry Consortium for Wind Energy Research, Education and Workforce Development. The meeting attracted wind experts from throughout the nation and included discussions of wind energy integration in the Eastern Interconnection, wind energy research, education and workforce development.



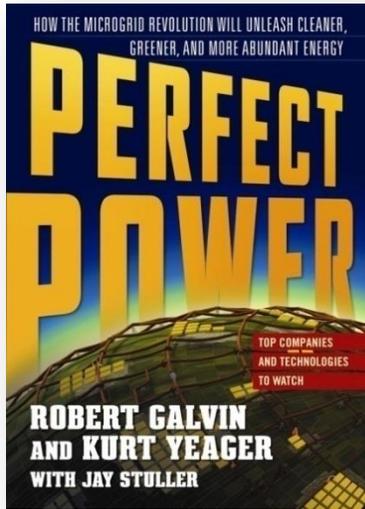
Advancing Wind Power in Illinois Conference



On July 21-22, 2011, the Galvin Center partnered with Illinois State University to host the Illinois Wind Working Group's annual "Advancing Wind Power in Illinois" conference. The two-day event covered issues related to wind energy research, deployment and policy issues.

The event brought nationally-recognized experts and local policymakers to Illinois to discuss wind energy.

Innovative Projects, Partnerships and Research



Perfect Power Project

Inspired by the leadership of Bob Galvin, the center's premier project is the development of the nation's first Perfect Power microgrid at IIT. When fully completed in the next year, the \$14 million project will equip IIT's microgrid with a new high-reliability distribution system for enhancing reliability, new sustainable energy sources (roof-top solar panels, wind generation units, flow batteries and charging stations for electric vehicles), and smart building automation technology (building controllers, Zigbee sensors, controllable loads) for energy efficiency and demand response. The high-reliability distribution system was completed in 2011, allowing IIT to eliminate blackouts on the microgrid.

In early 2012 the Galvin Center will conclude installation of next-generation smart electric vehicle charging infrastructure on the IIT microgrid. The project includes six Eaton Level 2 charging stations (5-6 hour charge time), and one Eaton DC Quick Charge station (15-20 minute charge time), and will be monitored and controlled by a smart grid master controller.



Additionally, the Galvin Center has begun installation of a next-generation smart grid-capable large-scale battery project on IIT's microgrid testbed for demonstration and evaluation. Produced by the ZBB Corporation, the 500 kWh zinc-bromide flow battery will be the first-of-its-kind in the U.S.

IIT Wind Energy Consortium

The Galvin Center is leading the University-Industry Consortium for Wind Energy Research, Education, and Workforce Development. Funded through a \$9 million U.S. Department of Energy grant, the consortium's research and development objectives focus on addressing several challenges identified in the DOE's "20 Percent Wind Energy by 2030" report.

The consortium consists of a diverse pool of public and private members working together to improve wind power reliability and performance, lower the price of wind energy, encourage greater integration into the utility grid, and build an educated workforce to drive the industry. Through the consortium, the Galvin Center is leading a number of groundbreaking research initiatives in all areas of wind energy.

On-Campus Wind Turbine – The Galvin Center's 8kW Viryd wind turbine located on IIT's Stuart Soccer Field is one of the nation's most visible wind turbines, dramatically increasing public awareness of urban wind power. The advanced design of this turbine allows for more electricity generation by alleviating fatigue loads caused by wind gusts and operating efficiently in all wind conditions.



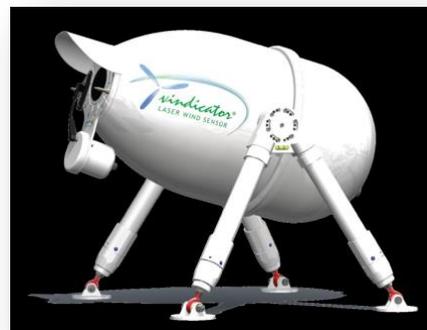
An **8kW Viryd lab turbine** allows researchers to pinpoint areas of stress on the turbine to gain insight as they work to find solutions to reduce the wear-and-tear of turbine components.





The Galvin Center's **1.5MW GE wind turbine**, located in LaSalle County, is outfitted with high-performing technology designed to increase its output and reduce wear and tear of components, which will ultimately increase the lifespan of the structure.

The technology is designed to detect problems within components before there is major damage to the wind turbine using vibration sensors, oil particulate sensors, temperature sensors, noise identification technology and other advanced detection hardware and software.



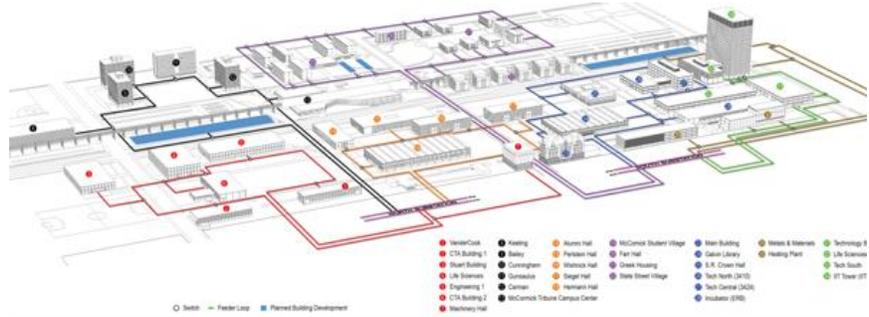
The turbine also features an innovative Catch-The-Wind Laser Wind Sensor to determine wind speed and direction in the undisturbed air 300 meters in front of the turbine. As a result, it gives the control system a predictive, three-dimensional view of actual conditions which allows for optimum wind turbine performance, reducing yaw error that can reduce performance and avoid unnecessary wear-and-tear.



Decreasing turbine noise is also important for the quality of life of residents and wildlife. As turbine noise decreases, more communities will be open to these energy generation structures. To address this critical issue, the Galvin Center is leading the IIT Acoustic Measurement Project (using phased arrays).

Korea Smart Grid Partnership

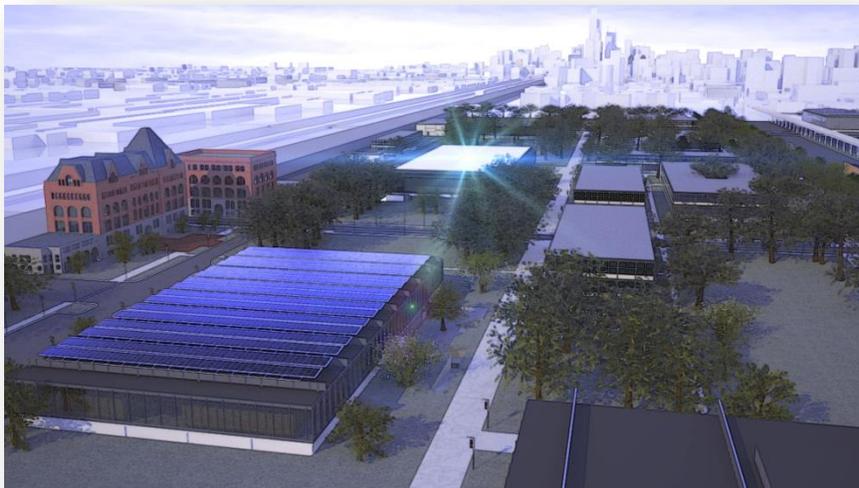
The Galvin Center is helping to lead the Illinois-Korea Smart Grid R&D Collaboration, a multi-million dollar international public-private partnership to accelerate the development of smart grid-supporting technology.



As part of this Collaboration, IIT has launched a project to deploy Phasor Measurement Unit (PMU) technology on its Perfect Power Microgrid. The \$3 million project, funded by the Republic of Korea and private industry partner ProCom, is installing 12 PMUs on the IIT microgrid to create a Local Area Monitoring System (LAMS) for microgrids.

Solar Innovation

The Galvin Center partnered with the City of Chicago Department of Environment, the Environmental Law & Policy Center, and West Monroe Partners to win a \$750,000 federal grant to help speed the adoption of rooftop solar deployment in Chicago.



The project will create an expedited solar permit process with online applications and applicant education materials that are transferable locally and regionally. The team is also working to implement a formal best practice solar zoning policy and develop solar-ready building standards.

The Galvin Center has also begun the planning phases for a next-generation smart solar installation on IIT microgrid testbed. The 60kW solar array and corresponding 60kW battery system will serve as a laboratory for new smart solar control technologies. The \$440,000 project is funded by the U.S. Department of Energy, the Illinois Department of Commerce and Economic Opportunity and IIT.

Illinois Smart Grid Regional Innovation Cluster

Over the past year the Galvin Center has launched the Illinois Smart Grid Regional Innovation Cluster, a consortium of innovation and economic development institutions working together to develop an emerging smart grid technology cluster in Illinois. The cluster is funded by a \$1.2 million contract with the U.S. Small Business Administration, and includes local partners Clean Energy Trust, the Illinois Science and Technology Coalition, and O-H Community Partners. The cluster supported ten local smart grid start-up companies, contributing to major successes such as:

Clean Urban Energy secured \$7 million Series A investment.

Power2Switch raised more than \$1.3 million in private funding.

Agentis secured two pilot programs with Midwest utilities.

Intelligent Generation secured pilot programs with several major utilities and will use the IIT Perfect Power platform for a test bed.

ZBB Energy entered into a \$600,000 project to install a 500 kWh Zinc Bromide Flow Battery on the IIT Perfect Power microgrid.



Collaborative Research and Development

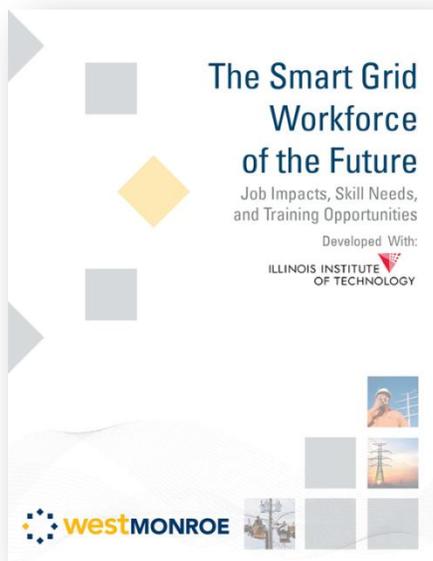
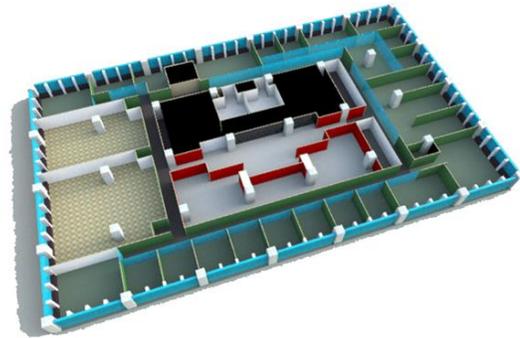
The Galvin Center is working with partners throughout the electricity industry on R&D projects, including:

- Distributed Energy Resource Integration
- Building Energy Management Systems
- Demand Response
- Electricity Markets
- New Transmission Infrastructure
- Plug-in Vehicles and Charging



Workforce Training and Education

The Galvin Center is home to the Smart Grid Workforce Education and Training Center - a \$12.6 million project, supported by the U.S. Department of Energy and the State of Illinois, to educate and train the nation's workforce to meet the global challenges and opportunities of the Smart Grid. This initiative will work to educate and train more than 49,000 people on Smart Grid and new energy topics over the course of three years, developing new curriculum through a network of partners, from K-12 programs to community colleges, university degree programs, and industry professional development short courses. A schedule of short courses is available at www.iit.edu/galvin_center/.



Smart Grid Workforce of the Future

In June 2011, the Galvin Center released a landmark report outlining the skill deficiencies of the existing workforce to meet the demands and needs of the Smart Grid economy of the future. The technologies and systems introduced through Smart Grid initiatives will require a new, highly-trained and flexible workforce to fully realize the smart grid promise. The future workforce will be vital to deploying and maintaining this national clean-energy smart grid infrastructure. Growing and training the smart grid workforce will only be possible if the industry commits to intensive, sophisticated, and integrated workforce-development initiatives.

To help address this critical issue, the Galvin Center, in collaboration with West Monroe Partners, commissioned and released a report as an initial step toward addressing the national workforce challenge. The research performed was able to:

- Identify the jobs impacted by the smart grid
- Capture the level of smart grid impact on these jobs
- Define critical smart grid skills requirements
- Evaluate current training opportunities available to address smart grid skill requirements

The resulting report was released last summer and provided critical insight to the specific job impacts, skill competencies, and current training landscape associated with the introduction of smart grid technologies. The report can be found at www.iit.edu/galvin_center/.

Affiliated Organizations

Perfect Power Institute

The Perfect Power Institute is transforming the way power systems are designed and operated, creating space for engaging consumers and communities in a safe, reliable, clean, and affordable electricity system.

The Institute administers the Perfect Power Seal of Approval (PPSoA) program, a rating system for the grid that establishes much-needed metrics to empower consumers, businesses, communities and regulators to create dramatically better performance from the power system.

As the U.S. moves toward a more intelligent, cleaner electricity system, a growing number of consumers are demanding improvements in power delivery as well as greater choice in the type of power they use and how they use it. The PPSoA program provides much-needed metrics and design criteria that help industry stakeholders.



By looking at power systems across four key consumer-focused categories—Reliability, Cost, Efficiency and Environment, and Consumer Empowerment—the PPSoA allows consumers, communities, regulators, vendors, utilities, policymakers and others to both evaluate and set the standard for system performance that best meets our 21st century power needs.

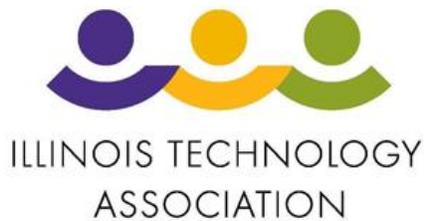


Institute for Sustainable Energy Development

The Institute for Sustainable Energy Development is a not-for-profit corporation dedicated to supporting the development of sustainable models for energy production and consumption.

The Institute for Sustainable Energy Development 's mission is to support the development and transfer of knowledge and technology that can facilitate new models for energy production and consumption that can help to better manage system costs, improve reliability, and reduce the environmental impact of energy consumption.

Achievements of the Galvin Center Members



Technologist of the Year Award

Illinois Technology Association

Presented for the championing of true technology innovation, either through new application of existing technology or the development of technology to achieve a truly unique product or service.

Outstanding Engineer Award

*Institute of Electrical and Electronics Engineers -
Power and Energy Society*

Presented for significant leadership and contributions towards IIT's Perfect power microgrid, the IIT wind consortium, and the Smart Grid Education and workforce development project.



Innovative Program Award

Electrical and Computer Engineering Department Heads Association

Presented for leadership in the development of an innovative energy research program at IIT.

Ongoing and Newly Funded Projects

1. A World-Class Smart Grid Education and Workforce Training Center, (\$12,600,000 total), DOE
2. Battery and Charging Stations for Perfect Power System, (\$1,000,000 total)
3. Illinois Smart Grid Regional Innovation Cluster, \$1,300,000, Small Business Administration (SBA)
4. Perfect Power System at IIT, (\$12,000,000 total), DOE
5. A World-Class University-Industry Consortium for Wind Energy Research, Education, and Workforce Development, (\$9,000,000 total)
6. Illinois Smart Solar Initiative, \$220,000, Illinois Department of Commerce and Economic Opportunity)
7. Local Area Monitoring System (LAMS) for Microgrid, \$400,000, KERI
8. Stochastic Optimization and Coordination Control of Demand Response for Enhancing the Secure and Economic Operation of Power Systems, (\$300,000), NSF
9. Wind Integration in the U.S. Eastern Interconnection, \$750,000, DOE
10. Coordination of Renewable Hydro-Wind Units for Enhancing the Hydrothermal Power System Operation, \$350,000, National Science Foundation

Technical Papers Published in the Last Year

1. L. Wu, M. Shahidehpour, and Z. Li, "Comparison of Scenario-Based and Interval Optimization Approaches to Stochastic SCUC," IEEE Transactions on Power Systems, (in print)
2. F. Aminifar, M. Fotuhi-Firuzabad, M. Shahidehpour, and A. Safdarian, "Impact of WAMS Malfunction on Power System Reliability Assessment," IEEE Transactions on Smart Grid, (in print)
3. L. Abreu, M. Khodayar, M. Shahidehpour, L. Wu, "Risk-Constrained Coordination of Cascaded Hydro Units with Volatile Wind Power Generation" IEEE Transactions on Sustainable Energy, (in print)
4. C. Sahin, M. Shahidehpour, and I. Erkmén "Generation Risk Assessment in Volatile Conditions with Wind, Hydro, and Natural Gas Units" Applied Energy, (in print)
5. M. Khodayar, L. Wu, and M. Shahidehpour, "Hourly Coordination of Electric Vehicle Operation and Volatile Wind Power Generation in SCUC," IEEE Transactions on Smart Grid, (in print)
6. W. Tian, M. Shahidehpour, and Z. Li, "Analysis of 2030 Large-Scale Wind Energy Integration in the Eastern Interconnection Using WINS," Electricity Journal, Vol. 24, No. 8, pp. 71-87, Oct. 2011
7. A. Khodaei, M. Shahidehpour, and S. Bahramirad, "SCUC With Hourly Demand Response Considering Intertemporal Load Characteristics," IEEE Transactions on Smart Grid, Vol. 2, No. 3, pp. 564-571, Sept. 2011
8. J. Choi, J. Park, T. Oh, K. Cho, J. Mitra, M. Shahidehpour, "Web Based Online Real-Time Information System for Reliability of Electrical Energy Supply Including WTG," Journal of International Council on Electrical Engineering, Vol. 1, No. 3, pp. 281-287, July 2011
9. J. Choi, J. Park, T. Oh, K. Cho, S. Hong, M. Shahidehpour, "Probabilistic Reliability Evaluation of Composite Power Systems Including Wind Turbine Generators," Journal of International Council on Electrical Engineering, Vol. 1, No. 3, pp. 274-280, July 2011
10. L. Wu and M. Shahidehpour, "Optimal Coordination of Stochastic Hydro and Natural Gas Supplies in Midterm Operation of Power Systems," IET Journal on Generation, Transmission & Distribution, Vol. 5, No. 5, pp. 577-587, May 2011
11. C. Liu, M. Shahidehpour, J. Wang, "Coordinated Scheduling of Electricity and Natural Gas Infrastructures with a Transient Model for Natural Gas Flow," Chaos (American Institute of Physics), Vol. 21, pp. 025102-1 through 025102-12, May 2011
12. C. Sahin, Z. Li, M. Shahidehpour, and I. Erkmén, "Impact of Natural Gas System on Risk-Constrained Midterm Hydrothermal Scheduling," IEEE Transactions on Power Systems, Vol. 26, No. 2, pp. 520-531, May 2011
13. A. Lotfjou, M. Shahidehpour, and Y. Fu, "Hourly Scheduling of DC Transmission Lines in SCUC With Voltage Source Converters," IEEE Transactions on Power Delivery, Vol. 26, No. 2, pp. 650-660, April 2011
14. F. Aminifar, M. Fotuhi-Firuzabad, M. Shahidehpour, and A. Khodaei, "Observability Enhancement by Optimal PMU Placement Considering Random Power System Outages," Energy Systems, Vol. 2, pp. 45-65, 2011

15. P. Maghoul, S. Hosseini, M. Oloomi Buygi, and M. Shahidehpour, "A Scenario-Based Multi-Objective Model for Multi-Stage Transmission Expansion Planning," IEEE Transactions on Power Systems, Vol. 26, No. 1, pp. 470-478, Feb. 2011
16. Li, J.; Li, Z.; Ren, K.; Liu, X.; , "Towards Optimal Electric Demand Management for Internet Data Centers," *Smart Grid, IEEE Transactions on* , vol.PP, no.99, pp.1, 0
17. Yanling Yuan; Zuyi Li; Kui Ren; , "Modeling Load Redistribution Attacks in Power Systems," *Smart Grid, IEEE Transactions on* , vol.2, no.2, pp.382-390, June 2011
18. Hassan Khorashadi Zadeh, Zuyi Li, Adaptive load blinder for distance protection, *International Journal of Electrical Power and Energy Systems*, Volume 33, Issue 4, May 2011, Pages 861-867
19. H. Khorashadi Zadeh and Zuyi Li, "Phasor Measurement Unit Based Transmission Line Protection Scheme Design," *Electric Power Systems Research*, pp. 421-429, February 2011.
20. Khodaei and M. Shahidehpour, "Optimal Operation of a Community-based Microgrid," in *Proceedings of the 2011 IEEE-ISGT-Australia Conference*, Perth, Australia, Oct. 2011
21. M. Shahidehpour, "Smart Grid Education and Workforce Training Center," in *Proceedings of the 2011 IEEE-ISGT-Australia Conference*, Perth, Australia, Oct. 2011
22. Optimal Operation of a Community-based Microgrid," in *Proceedings of the 2011 IEEE-ISGT-Australia Conference*, Perth, Australia, Oct 2011
23. K. Cho; J. Park, T. Oh, J. Choi, A. El-Keib, M. Shahidehpour; "Probabilistic Reliability Criterion for Expansion Planning of Grids Including Wind Turbine Generators," in Proceedings of the 2011 IEEE Power & Energy Society General Meeting, Detroit, July 2011

Books Published in the Last Year

1. M. Shahidehpour, Z. Li and Y. Fu, Energy System Control and Operation, John Wiley and Sons
2. M. Shahidehpour and L. Wu, Stochastic Methods in Electric Power Systems, John Wiley and Sons

Invited Lectures and Speeches in the Last Year

1. Sharif University of Technology, Tehran, Iran
2. King Abdulaziz University, Jeddah, Saudi Arabia
3. K.N. Toosi University, Iran
4. Cigre Conference on Electric Power System of Future, University of Bologna, Italy
5. Tianjin University, Tianjin, China
6. Annual Meeting of Electrical Engineering Department Head Association, Phoenix
7. University of Nevada, Reno
8. Illinois Science & Technology Coalition Meeting at the U.S. Capitol, Washington, DC
9. U.S. Department of Energy Workshop on Workforce Development, Washington, DC
10. National Renewable Energy Laboratory, Boulder
11. Achievement Rewards for College Scientists (ARC) Foundation, Chicago
12. Stuart School of Business, IIT, Chicago
13. IIT Alumni Association, Anaheim
14. "Growing Chicago's Green Energy Economy", ELPC, Chicago
15. Great Lakes Symposium on Smart Grid and the New Energy Economy, Chicago

16. "Smart Grid Done Right" Workshop, Springfield
17. 25x'25 Renewable Energy Forum, Chicago
18. Gridwise Smart Grid Workforce of the Future Workshop, Chicago

Keynote Talks Delivered at International Conferences

- 2011 IEEE ISGT Conference-Australia, Perth, Australia
- 2011 IEEE ISGT Conference-Middle East, Jeddah, Saudi Arabia
- 2011 DRPT Conference, Weihai, Shandong, China
- 2011 ICEE Conference, Amirkabir University, Tehran, Iran

Editorship Positions at Publications

Society/Journal	Office Held
IEEE/Power and Energy Society	VP of Publications & General Chair, 2012 IEEE
IEEE	Editor-in-Chief, IEEE Transactions on Smart Grid
IEEE/Power and Energy Society	General Chair, Innovative Smart Grid Technologies Conference
The Electricity Journal	Member of the Editorial Board
Energy Systems Journal	Member of the Editorial Board
KIEE Journal of Power Engineering	Member of the Editorial Board
Journal of Emerging Electric Power	Member of the Editorial Board
IEEE Power and Energy Magazine	Member of the Editorial Board
IEEE Transactions on Power Delivery	Editor
Electric Power Components and Systems (Journal)	Member of the Editorial Board
IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing	Member of the Editorial Board
International Journal on Power System Optimization	Member of the Editorial Board
IEEE Transactions on Smart Grid, Special Issue on Cyber, Physical and System Security in Smart Grid	Guest Editor