



Power Systems Engineering Research Center

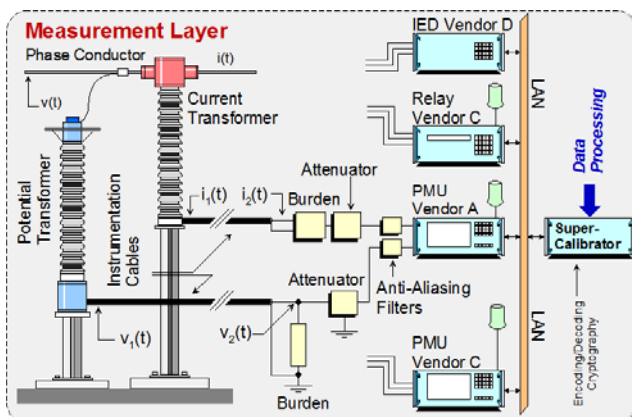
The electric power industry is evolving from its historical business structure. Challenges for success in this demanding business environment are being raised by a new direction for the industry toward low-carbon technologies, new market structures and ways of doing business, new smart grid technologies, the demands of customers for customized services, strategic choices between centralized and decentralized technologies, and a graying industry that needs well-trained power engineers. Achieving high penetration of renewable generation technologies has become a major driver for change. Yet the basic function of the industry – to produce and to deliver power, safely and reliably – has not changed. The challenges call for new strategies, technologies, analytical capabilities and tools, and operating practices, along with sound public policy guidance.

As a National Science Foundation Industry-University Cooperative Research Center, the Power Systems Engineering Research Center (PSERC) draws on university capabilities to creatively address these challenges. ***Its core purpose is to empower minds to engineer the future electric energy system.*** Under the banner of PSERC, multiple U.S. universities are working collaboratively toward:

- An efficient, secure, resilient, adaptable, and economic electric power infrastructure serving society
- A new generation of educated technical professionals in electric power
- Knowledgeable decision-makers on critical energy policy issues
- Sustained, quality university programs in electric power engineering.

PSERC provides:

- efficient access to experienced university researchers in an array of relevant disciplines and geographically located across the U.S.



Developed by PSERC researchers, the SuperCalibrator is a distributed state estimator that uses detailed models of substations and measurements from all substation devices to provide power operators with real-time information that can help them avoid blackouts and improve the efficiency of the grid.



PSERC research has resulted in the development and commercialization of advanced visualization tools to help power system operators improve the situational awareness of their power systems.

- leading-edge research in cost-effective projects jointly developed by industry leaders and university experts
- high quality education of future power engineers.

The multidisciplinary expertise of PSERC's researchers includes power systems, applied mathematics, complex systems, computing, control theory, power electronics, operations research, non-linear systems, economics, industrial organization and public policy. We partner with private and public organizations that provide integrated energy services, transmission and distribution services, power system planning, control and oversight, market management services, and public policy development.

Education Program

The undergraduate and graduate power programs at PSERC's collaborating universities produce engineers capable of making substantive contributions in today's complex power industry. By taking innovative research findings to the classroom and involving students in our research, PSERC faculty introduce students to the cutting edge of power system technologies, analytical techniques and industry practices. Not only does PSERC help students become technically prepared for their next job, it also assures that they will be knowledgeable about the challenges and trends transforming the industry. PSERC also facilitates efficient employment searches through industry-student interactions at industry meetings, student involvement in PSERC projects, web site postings, email announcements, and an on-line career service for students.

Through monthly webinars and on-site seminars, PSERC meets continuing education needs of engineers from our industrial partners. The PSERC website, available at www.pserc.org, has tutorials, analysis tools and archived webinars along with papers, reports and presentations by our researchers.

Research Program

PSERC's comprehensive research program spans power markets, T&D technologies and power systems to create a modern electric energy infrastructure that enables a low-carbon economy that serves society.

Systems Research: Systems research seeks ways to increase use, efficiency and reliability of increasingly complex and dynamic power systems. Current research topics are transmission corridors to support renewable energy resources, integration of storage devices with renewable, special protection schemes, visualization using PMU data, synchrophasor application framework, on-line security assessment, and model and data interoperability in a smart grid.

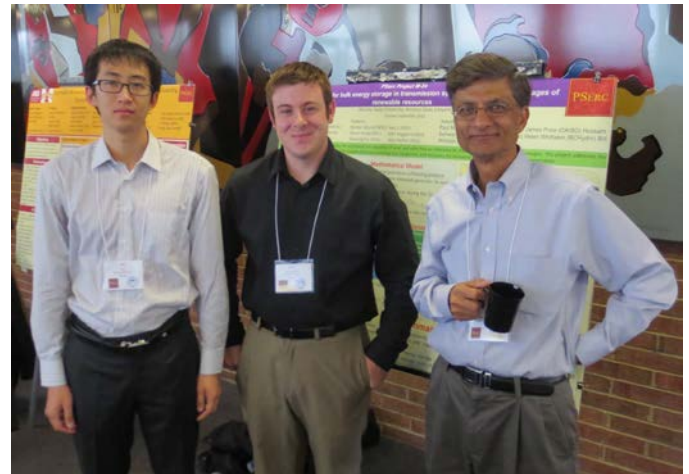
Markets Research: Markets research focuses on planning, design and operation of smart markets for a smart electric grid. Current research topics include implications of greenhouse gas policy options for power systems, coupling wind generation with controllable load and storage, demand response options for integrating renewable energy, and interactions of energy and environmental policies in a transmission constrained electric power market.

Transmission and Distribution Research: This research improves performance of T&D systems by finding new applications for innovative technologies. Current research projects include new substation designs, communication requirements for a smart grid, PHEV's for energy storage, smart grid implications for distribution engineering, interoperability of PMU's and PMU-enabled intelligent electronic devices, and micro and nano dielectrics for utility applications.

Leveraged Funding: PSERC has two major research efforts supported by the U.S. DOE. One is the [Future Grid Initiative](#) to investigate requirements for a systematic transformation of today's electric grid to support high penetrations of highly variable distributed energy resources. The other is work with the [Consortium for Electric Reliability Technology Solutions](#) formed in 1999 to research, develop, and disseminate new methods, tools, and technologies to protect and enhance the reliability of the U.S. electric power system, and to support efficient markets.



PSERC researchers are investigating new approaches to efficiently test and validate data sources and applications. Several PSERC universities have facilities, such as shown here at Washington State University, for testing and validating phasor measurement based devices and algorithms.



Interactions among industry members and PSERC students are facilitated at PSERC meetings through student posters and through a session for career conversations. PSERC members also receive student resumes.

Current Industry Members

ABB	American Electric Power
American Transmission	Arizona Public Service
Bonneville Power Admin.	California ISO
CenterPoint Energy	Dominion Virginia Power
ENGIE	Entergy
EPRI	Exelon
First Energy	First Solar
GE	GE Grid Software Solutions
Guangdong Power Grid	Idaho Power
Institut de Recherche d'Hydro-Québec (IREQ)	ISO New England
Midcontinent ISO	National Renewable Energy Lab
National Rural Elec. Coop.	New York ISO
New York Power Authority	Pacific Gas and Electric
PJM Interconnection	PowerWorld Corp.
RTE - France	Salt River Project
Southern Company	Southwest Power Pool (SPP)
The Energy Authority	Tri-State G&T Cooperative
U.S. Dept. of Energy	Western Area Power Admin.

Collaborating Universities

Arizona State Univ.	Texas A&M Univ.
Carnegie Mellon Univ.	Washington State Univ.
Colorado School of Mines	Wichita State Univ.
Cornell Univ.	Univ. of Calif. at Berkeley
Georgia Inst. of Technology	Univ. of Illinois at Urb.-Cham.
Howard Univ.	Univ. of Wisconsin-Madison
Iowa State Univ.	

For More Information

Visit our web site at <http://www.pserc.org> or contact:

Vijay Vittal, Director
Arizona State Univ. (PSERC's lead university)
Phone: 480-965-1879
Email: Vijay.Vittal@asu.edu

Markets Research Projects

Markets research focuses on planning, design and operation of smart markets for a smart electric grid.

Current Projects (visit the PSERC website at: http://pserc.wisc.edu/research/current_projects.aspx)

- Risk Assessment of Constraint Relaxation Practices (ends in 2017, M-34)
- Reliability Metrics for Renewable Resources and Self-Reserves (ends in 2017, M-33)
- New Operation Tools for Improving Flexibility and Reliability of Systems with Variable Resources and Storage Devices (ends in 2016, M-32)
- Markets for Ancillary Services in the Presence of Stochastic Resources (ends in 2016, M-31)

Completed Projects (visit the PSERC website at: http://pserc.wisc.edu/research/public_reports.aspx)

- A Framework for Transmission Planning Under Uncertainty (2015, M-30)
- Constraint Relaxations: Analyzing the Impacts on System Reliability, Dynamics, and Markets (2015, M-29)
- Analytical Methods for the Study of Investment Strategies in Compliance with Environmental Policy Requirements (2013, M-28)
- Impact of Bad Data and Cyber Data Attack on Electricity Market Operation (2013, M-27)
- Quantifying Benefits of Demand Response and Look-ahead Dispatch in Support of Variable Resources (2013, M-26)
- The Development and Application of a Distribution Class LMP Index (2013, M-25)
- Interactions of Multiple Market-based Energy and Environmental Policies in a Transmission-Constrained Competitive National Electricity Market (2012, M-24)
- Design and Valuation Design and Valuation of Demand Response Mechanisms and Instruments for Integrating Renewable Generation Resources in a Smart Grid Environment (2012, M-23)
- Coupling Wind Generation with Controllable Load and Storage: A Time-Series Application of the SuperOPF (2012, M-22)
- Integration of Storage Devices into Power Systems with Renewable Energy Sources (2012, S-40)
- PHEVs as Dynamically Configurable Dispersed Energy Storage (2011, T-40)
- Technical and Economic Implications of Greenhouse Gas Regulation in a Transmission Constrained Restructured Electricity Market (2010, M-21)
- Improved Investment and Market Performance Resulting from Proper Integrated System Planning (2010, M-18)
- Optimal Electricity Market Structures to Reduce Seams and Enhance Investment (2010, M-9)
- Facilitating Environmental Initiatives While Maintaining Efficient Markets and Electric System Reliability (2009, M-20)
- Integrated Financial and Operational Risk Management in Restructured Electricity Markets (2009, M-17)
- Integrating Electric System Planning with Efficient Markets to Provide Adequate Investment (2009, M-16)
- Economic Impact Assessment of Transmission Enhancement Projects (2009, M-14)
- Tools for Assessment of Bidding into Electricity Auctions (2008, M-15)
- Agent Modeling for Integrated Power System, Power and Fuel Market Simulation (2008, M-13)
- Reliability, Electric Power, and Public Vs. Private Goods: A New Look at the Role of Markets (2008, M-12)

- Evaluation of Alternative Market Structure and Compensation Schemes for Incenting Transmission Reliability and Adequacy Related Investments (2008, M-11)
- Electric Power Industry and Climate Change – Discussion Paper (2007, M-19)
- Uncertain Power Flows and Transmission Expansion Planning (2007, M-10)
- Reliability Assessment Incorporating Operational Considerations and Economic Aspects for Large Interconnected Grids (2007, M-8)
- Modeling Market Signals for Transmission Adequacy Issues: Valuation of Transmission Facilities and Load Participation Contracts in Restructured Electric Power Systems (2007, M-6)
- Software Agents for Market Design and Analysis (2005, M-5)
- Market Redesign: Incorporating the Lessons Learned from Actual Experiences for Enhancing Market Design (2005, M-4)
- Structuring Electricity Markets for Demand Responsiveness: Experiments on Efficiency and Operational Consequences (2004, M-7)
- Market Interactions and Market Power (2003, M-3)
- Market Mechanisms for Competitive Electricity (2002, M-2)
- Reactive Power Support Services in Electricity Markets (2000, M-1)

Systems Research Projects

Systems research concentrates on efficient and reliable operation of the increasingly complex and dynamic power system.

Current Projects (visit the PSERC website at: http://pserc.wisc.edu/research/current_projects.aspx)

- Attack-Resilient and Secure EMS: Design, Algorithms, Operational Protocols, and Evaluation (ends in 2018, S-72)
- Real-time Synchrophasor Data Quality Analysis and Improvement (ends in 2018, S-71)
- Leveraging Conservation Voltage Reduction for Energy Efficiency, Demand Side Control and Voltage Stability Enhancement in Integrated Transmission and Distribution Systems (ends in 2018, S-70)
- Representation, Modeling, Data Development and Maintenance of Appropriate Protective Relaying Functions in Large Scale Transient Stability Simulations (ends in 2017, S-66)
- Real Time Synchrophasor Measurements Based Voltage Stability Monitoring and Control (ends in 2017, S-65)
- Monitoring and Maintaining Limits of Area Transfers with PMUs (ends in 2017, S-64)
- Advanced Cyber-Physical Analysis for Smart Grid Distributed ICT and IED Resources at RTE France (ends in 2017, S-63G)
- Mitigating Adverse Impacts of Negative Damping Induced by Wind Generators on Power Grid Dynamics (ends in 2016, S-69G)
- Non-Minimum-Phase Dynamics in the Electric Power Transmission Network: Identification, Analysis, and Preserving Model Reduction (ends in 2016, S-68G)
- Cloud Data Sharing Platform (ends in 2016, S-67G)
- Load Model Complexity Analysis and Real-Time Load Tracking (ends in 2016, S-60)
- Sparse Sensing Methods for Model-Free Sensitivity Estimation and Topology Change Detection using Synchro-Phasor Measurements (ends in 2016, S-59)
- Hybrid Time Domain Simulation: Application to Fault Induced Delayed Voltage Recovery (ends in 2016, S-58)

Completed Projects (visit the PSERC website at: http://pserc.wisc.edu/research/public_reports.aspx)

- Seamless Grid Management (2015, S-62G)
- Day-ahead and Real-Time Models for Large-Scale Energy Storage (2015, S-61G)
- Adaptive and Intelligent PMUs for Smarter Applications (2015, S-57)
- Stability, Protection and Control of Systems with High Penetration of Converter Interfaced Generation (2016, S-56)
- Toward Standards for Dynamics in Electric Energy Systems (2016, S-55)
- Towards a Privacy-Aware Information-Sharing Framework for Advanced Metering Infrastructures (2015, S-54)
- Seamless Energy Management Systems Part I: Assessment of Energy Management Systems and Key Technological Requirements (2014, S-53G – Part I)
- Seamless Energy Management Systems Part II: Development of Prototype Core Elements (2014, S-53G – Part II)
- Coordinated Aggregation of Distributed Demand-Side Resources (2014, S-52)
- The Application of Robust Optimization in Power Systems (2014, S-51)
- Real Time PMU-Based Stability Monitoring (2014, S-50)
- Exploiting Emerging Data for Enhanced Load Modeling (2014, S-49)

- Testing and Validation of Phasor Measurement Based Devices and Algorithms (2013, S-45)
- Data Mining to Characterize Signatures of Impending System Events or Performance from PMU Measurements (2013, S-44)
- Setting-less Protection Methods (2012, S-48G)
- Integrated EMS for Seamless Power System Analytics (2012, S-47G)
- Seamless Power System Analytics (2012, S-46G)
- Low Frequency Transmission for Wind Farm Power (2012, S-42)
- Tools and Techniques for Considering Transmission Corridor Options to Accommodate Large Scale Renewable Energy Resources (2012, S-41)
- Integration of Storage Devices into Power Systems with Renewable Energy Sources (2012, S-40)
- The Smart Grid Needs: Model and Data Interoperability, and Unified Generalized State Estimator (2012, S-39)
- Toward a Systematic Framework for Deploying Synchrophasors and their Utilization for Improving Performance of Future Electric Energy Systems (2012, S-37)
- Validation and Accreditation of Transient Stability Results (2011, S-43G)
- Next Generation On-Line Dynamic Security Assessment (2011, S-38)
- Techniques for the Evaluation of Parametric Variation in Time-Step Simulations (2011, S-17)
- Using PMU Data to Increase Situational Awareness (2010, S-36)
- System Protection Schemes: Limitations, Risks, and Management (2010, S-35)
- Implementation Issues for Hierarchical, Distributed State Estimators (2010, S-33)
- Fast Simulation, Monitoring, and Mitigation of Cascading Failures (2010, S-32)
- Real-Time Security Assessment of Angle Stability and Voltage Stability Using Synchrophasors (2010, S-31)
- Impact of Increased DFIG Wind Penetration on Power System Reliability and Consequent Market Adjustments (2009, S-34)
- Development and Evaluation of System Restoration Strategies from a Blackout (2009, S-30)
- Detection, Prevention and Mitigation of Cascading Events – Prototype Implementations (2008, S-29)
- Preventing Voltage Collapse with Protection Systems that Incorporate Optimal Reactive Power Control (2008, S-28)
- Decision Tree Based Online Voltage Security Assessment Using PMU Measurements (2008, S-27G)
- Risk of Cascading Outages (2008, S-26)
- Effective Power System Control Center Visualization (2008, S-25)
- Optimal Allocation of Static and Dynamic VAR Resources (2008, S-24)
- Enhanced State Estimators (2006, S-22)
- Security Enhancement through Direct Non-Disruptive Load Control: Part I, Part II (2006, S-16)
- Optimal Placement of Phasor Measurement Units for State Estimation (2005, S-23G)
- On-Line Transient Stability Assessment Scoping Study (2005, S-21)
- New Implications of Power System Fault Current Limits (2005, S-20)
- Detection, Prevention and Mitigation of Cascading Events: Part I, Part II, Part III (2005, S-19)
- Visualization of Power Systems and Components (2005, S-18)
- Extended State Estimation for Synchronous Generator Parameters (2005, S-15)
- Comprehensive Power System Reliability Assessment (2005, S-13)

- New System Control Methodologies (2005, S-6)
- Risk-Based Maintenance Allocation and Scheduling for Bulk Transmission System Equipment (2003, S-14)
- Integrated Security Analysis (2003, S-7)
- Robust Control of Large-Scale Power Systems (2002, S-12)
- Steady State Voltage Security Margin Assessment (2002, S-11)
- Power System State Estimation and Optimal Measurement Placement for Distributed Multi-Utility Operation (2002, S-10)
- Coordination of Transmission Line Transfer Capabilities (2002, S-8)
- Voltage Collapse Margin Monitor (2002, S-2)
- Identification and Tracking of Parameters for a Large Synchronous Generator (2002, S-1)
- Automated Operating Procedures for Transfer Limits (2001, S-5)
- Impact of Protection Systems on Reliability (2001, S-4)
- Avoiding and Suppressing Oscillations (2000, S-3)

T&D Technologies Research Projects

T&D research improves transmission and distribution systems through use of technology innovations.

Current Projects (visit the PSERC website at: http://pserc.wisc.edu/research/current_projects.aspx)

- Life-cycle Management of Mission-Critical Systems through Certification, Commissioning, In-Service Maintenance, Remote Testing, and Risk Assessment (ends in 2018, T-57HI)
- Life-cycle Management of Mission-Critical Systems through Certification, Commissioning, In-Service Maintenance, Remote Testing, and Risk Assessment (ends in 2017, T-57)
- Setting-less Protection (Part II): Field Demonstrations (ends in 2016, T-56G)
- Setting-less Protection (Part I): Centralized Substation Protection (ends in 2016, T-55G)
- Reliability Assessment and Modeling of Cyber Enabled Power Systems with Renewable Sources and Energy Storage (ends in 2016, T-53)

Completed Projects (visit the PSERC website at: http://pserc.wisc.edu/research/public_reports.aspx)

- Establishing a Controls Laboratory for Training, Research and Development, and Experimentation (2015, T-54G)
- Systematic Integration of Large Data Sets for Improved Decision-Making (2015, T-51)
- Setting-less Protection Methods: Laboratory Demonstrations (2014, T-52G)
- The Electricity and Transportation Infrastructure Convergence Using EVs (2014, T-50G)
- The Economic Case for Bulk Energy Storage in Transmission Systems with High Percentages of Renewable Resources (2014, T-48)
- Making the Economic Case for Innovative HTLS Overhead Conductors (2014, T-47)
- Setting-less Protection (2013, T-49G)
- The Next Generation EMS Design (2013, T-45)
- Distribution System Analysis Tools for Studying High Penetration of PV with Grid Support Features (2013, T-44)
- Evaluation of RTV Coated Station Insulators (2012, T-46G)
- Verifying Interoperability and Application Performance of PMUs and PMU-Enabled IEDs at the Device and System Level (2012, T-43)
- Micro and Nano Dielectrics for Utility Applications (2012, T-42)
- Communication Requirements and Integration Options for Smart Grid Deployment (2012, T-39)
- Implications of the Smart Grid Initiative on Distribution Engineering, Part 1, Part 2, Part 3, Part 4 (2011, T-41)
- PHEVs as Dynamically Configurable Dispersed Energy Storage (2011, T-40)
- Transformer Overloading and Assessment of Loss-of-Life for Liquid-Filled Transformers (2011, T-25)
- Substation of the Future: A Feasibility Study (2010, T-38)
- The 21st Century Substation Design (2010, T-37)
- Comparative Characterization of Parallel Distribution Sensors Under Field Conditions (2010, T-35)
- Integration of Asset and Outage Management Tasks for Distribution Applications (2009, T-36)
- Power System Level Impacts of Plug-In Hybrid Vehicles (2009, T-34)
- Characterization of Composite Cores for High Temperature-Low Sag Conductors (2009, T-33)

- Integration of Substation IED Information into EMS Functionality (2008, T-32)
- Massively Deployed Sensors (2008, T-31)
- Transient Testing of Protective Relays: Study of Benefits and Methodology (2008, T-30)
- Digital Protection System Using Optical Instrument Transformers and Digital Relays Interconnected by an IEC 61850-9.2 Digital Process Bus (2008, T-29)
- Satellite Imagery for the Identification of Interference with Overhead Power Lines (2008, T-28)
- Reliability-Based Vegetation Management Through Intelligent System Monitoring (2007, T-27)
- Prediction of Flashover Voltage of Insulators Using Low Voltage Surface Resistance Measurement (2006, T-26G)
- Risk-Based Maintenance Resource Allocation for Distribution System Reliability Enhancement (2006, T-24)
- Novel Approach for Prioritizing Maintenance of Underground Cables (2006, T-23)
- Performance Assessment of Advanced Digital Measurement and Protection Systems: Part I, Part II (2006, T-22)
- Automated Integration of Condition Monitoring with an Optimized Maintenance Scheduler for Circuit Breakers and Power Transformers (2006, T-19)
- Control and Design of Microgrid Components (2006, T-18)
- Enhanced Reliability of Power System Operation Using Advanced Algorithms and IEDs for On-Line Monitoring: Part I, Part II (2005, T-17)
- Voltage Sag Effect on Loads in Electric Power Systems (2005, T-16)
- Distribution System Electromagnetic Modeling and Design for Enhanced Power Quality (2005, T-12)
- Distributed Electric Energy Storage and Generation (2004, T-21)
- Smart Sensor Development for Power Transmission and Distribution: Optical Sensor for Transformer Monitoring (2004, T-20)
- Evaluation of Critical Components of Non-Ceramic Insulators In-Service: Role of Seals and Interfaces (2004, T-14)
- Intelligent Substation (2004, T-5)
- Personnel Grounding and Safety Issues / Solutions Related to Servicing Telecommunications Equipment Connected to Fiber Optic Cables in Optical Ground Wire (OPGW) (2002, T-13)
- Power System Monitoring Using Wireless Substation and System-Wide Communications: Part I, Part II (2002, T-11)
- Accurate Fault Location in Transmission and Distribution Networks Using Modeling, Simulation and Limited Field-Recorded Data (2002, T-10)
- Enhanced State Estimation via Advanced Substation Monitoring (2002, T-9)
- Investigation of Fuel Cell Operation and Interaction within the Surrounding Network (2002, T-8)
- Condition Monitoring and Maintenance Strategies for In-Service Non-ceramic Insulators, Underground Cables and Transformers (2002, T-6)
- Differential GPS Measurement of Overhead Conductor Sag and Software Implementation (2002, T-2)
- Corona Discharge Caused Deterioration of All Dielectric Self-Supporting Fiber-Optic Cables (2002, T-1)
- Redesign and New Interpretation of Power Acceptability Curves for Three Phase Loads (2001, T-7)
- Electrical Transmission Line Insulator Flashover Predictor (2001, T-4)
- On-Line Peak Loading of Substation Distribution Transformers Through Accurate Temperature Prediction (2001, T-3)