



Power Systems Engineering Research Center

**PMU-Related
Research Projects of the Power Systems
Engineering Research Center**

April 2006

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1 Introduction

This document summarizes PSERC's completed and continuing projects. These projects are categorized by research stem: Markets, Systems and T&D Technologies. Section 2 provides an overview of status for the continuing projects. Section 3 gives summaries of completed projects. Finally, Sections 4-6 contain descriptions of the stem research areas plus detailed project descriptions and status. Reports, papers and presentations from the projects can be found on the PSERC website: <http://www.pserc.org>.

Questions and comments on PSERC's research program and projects is welcomed. This feedback should be sent to [Vijay Vittal](#), Director, and to the appropriate Stem Committee Chairs:

- [Richard Schuler](#), Markets Stem
- [Jim McCalley](#), Systems Stem
- [Jerry Heydt](#), T&D Technologies Stem

They are also interested in hearing from any industry member who may want to join the project teams. General information about PSERC is available on the [PSERC website](#).

The projects described in the report do not include the work being conducted by PSERC researchers with the Consortium for Electric Reliability Technology Solutions. Information about the CERTS program can be found at <http://certs.lbl.gov/>.

User Notes

This document contains links within the document as well as links to resources available on the PSERC website. Clicking on any link (indicated by blue characters) will take you to the new location within the document or to the linked Internet site. You will have to be connected to the Internet to take advantage of the links to website resources. The table of contents is also linked to the appropriate section of the report.

Another useful tip is that Adobe Acrobat contains a "back-button" just like a browser. This will allow you to browse from one location in the document to another, and then return.

2 Completed Systems Projects

2.1 Avoiding and Suppressing Oscillations (S-3)

Project	Avoiding and Suppressing Oscillations (S-3)
Summary	This determined the feasibility of computations to advise operators on how to avoid or suppress large-scale system oscillations. It provided the basic understanding of the problem, developed approaches to solving the problem, and tested them to determine their feasibility.
Project Team	Ian Dobson (Wisconsin – lead), Fernando Alvarado (Wisconsin), Chris DeMarco (Wisconsin), and Pete Sauer (Illinois)
Project Period	October 1997 to September 1999
Status	Final report available in the 2000 Reports folder . PSERC Document 00-01.

2.2 Integrated Security Analysis (S-7)

Project Name	Integrated Security Analysis (S-7)
Summary	This project is investigating the integration of existing tools for static, dynamic, voltage and steady-state stability security assessment into a comprehensive security analysis framework. The objective is to improve efficiency for determining security results from both off-line and on-line computations, and for effectively conveying those results to system operators. The project will exploit new concepts in intelligent systems.
Academic Team Members	Kevin Tomsovic (Washington State University – lead) and Pete Sauer (Illinois)
Project Period	October 1999 to September 2001
Status	Final report available in 2002 Reports folder. PSERC Document 02-41.

2.3 Coordination of Line Transfer Capability Ratings (S-8)

Project Name	Coordination of Line Transfer Capability Ratings (S-8)
Summary	Power transfer capacity is limited by non-linear phenomena including constraints on reactive power reserves, transient stability limits and damping of inter-area oscillations. This project will develop tools for computing optimal transfer capability of strategic transmission paths under power-flow and small-signal stability constraints.
Academic Team Members	Mani V. Venkatasubramanian (Washington State University – lead)
Project Period	October 1998 to September 2001
Status	Final report available in 2002 Reports folder. PSERC Document 02-28.

2.4 Visualization of Power Systems (S-9)

Project Name	Visualization of Power Systems (S-9)
Summary	This project's goal is to develop innovative methods to assist players in the electricity industry to extract and visualize knowledge concerning power system capacity and constraints. Researchers will explore the use of techniques for knowledge extraction using two-dimensional displays and a three-dimensional virtual environment.
Academic Team Members	Tom Overbye (Illinois – lead), Bob Thomas (Cornell), and Doug Wiegmann (Illinois)
Industry Team Members	TVA, Entergy, Wisconsin Electric, ComED, and WAPA.
Project Period	January 1, 2000 to December 31, 2001
Status	Final report available in 2002 Reports folder. PSERC Document 02-36.

2.5 Robust Control of Large-Scale Power Systems (S-12)

Project Name	Robust Control of Large-Scale Power Systems (S-12)
Summary	This research extends existing methods for robust stability analysis to deal with large-scale power system problems resulting in part from the restructuring of the electric power industry to achieve competitive market-based decision-making. It applies modern robust control methods to develop computationally tractable algorithms suitable for large-scale problems.
Research Stem	Systems
Academic Team Members	Vijay Vittal (Arizona State University – lead), Mustafa Khammash (Iowa State University), Chris DeMarco (University of Wisconsin), and Peter Young (Colorado State University)
Industry Team Members	Innocent Kamwa (IREQ) and Dale Stevens (MidAmerican)
Project Period	September 1, 2000 to August 31, 2002
Status	Final report available in 2002 Reports folder. PSERC Document 02-43.

2.6 Security Enhancement through Direct Non-Disruptive Load Control (S-16)

Project Name	Security Enhancement through Direct Non-Disruptive Load Control (S-16)
Summary	Incorporating direct load control at times when the system is vulnerable can significantly enhance system security. Modern technology facilitates direct load control schemes in which customer loads having special characteristics can be effectively controlled with minimum disruption to the customer. This project examines the benefits, methods of analysis, and potential control structures that can be used.
Research Stem	Systems
Academic Team Members	Ian Hiskens (Illinois-lead) Vijay Vittal (Arizona State)
Industry Team Members	Entergy (Sharma Kolluri) GE Power Systems (Nick Miller) IREQ Hydro Quebec (Innocent Kamwa)
Project Period	June 1, 2002 to August 31, 2005
Status	Reports for Parts I and II are available in Reports for Members Only Folder . PSERC Documents 06-01 and 06-02.

2.7 Visualization of Power Systems and Components (S-18)

Project Name	Visualization of Power Systems and Components (S-18)
Summary	Electric power systems are characterized by an overwhelming amount of data. The goal of this project is the continued development of better visualization techniques to help glean useable information from this data.
Research Stem	Systems
Academic Team Members	Tom Overbye (Illinois-lead) Doug Wiegmann (Illinois) and Sakis Meliopoulos (Georgia Tech)
Industry Team Members	TVA (Keith Morris and Warren Wu), Exelon (Dan Sleezer and David Schooley), ATC (Paul Walter and Don Morrow), WAPA (Paulette Kaptain), PowerWorld (Ray Klump and Jamie Weber)
Project Period	June 1, 2002 to August 31, 2005
Status	Final report available in the 2005 Reports Folder folder. PSERC Document 05-65.

2.8 Detection, Prevention and Mitigation of Cascading Events (S-19)

Project Name	Detection, Prevention and Mitigation of Cascading Events (S-19)
Summary	<p>This project will investigate novel approaches using new technologies to provide effective control of cascading disturbances and to enhance reliability. When a power system is subjected to large disturbances, and the vulnerability analysis indicates that the system is approaching a potential catastrophic failure, control actions need to be taken to steer the system away from severe consequences, and to limit the extent of the disturbance. We are approaching the problem in three steps:</p> <ol style="list-style-type: none"> 1. Detection of major disturbances and protective relay operations leading to cascading events. 2. Wide area measurement based remedial action. 3. Adaptive islanding with selective underfrequency load shedding.
Research Stem	Systems
Academic Team Members	Vijay Vittal (Arizona State University-lead) Mladen Kezunovic (Texas A&M) and Mani Venkatasubramanian (Washington State)
Industry Team Members	Hydro Quebec, IREQ (Innocent Kamwa) MidAmerican Energy (Miodrag Djukanovic) Entergy (Sharma Kolluri)
Project Period	June 1, 2002 to August 31, 2005
Status	Parts I, II and III are complete and available in the 2005 Reports Folder . PSERC Documents 05-59 to 05-61.

2.9 On-Line Transient Stability Assessment (S-21)

Project Name	On-Line Transient Stability Assessment (S-21)
Summary	Scoping study to review the state of the art and establish requirements for on-line transient stability analysis and preventive and corrective control following transient insecurity.
Research Stem	Systems
Academic Team Members	Lead: Vijay Vittal (Arizona State University) Team members: Peter Sauer (Univ. of Illinois) and Sakis Meliopoulos (Georgia Tech)
Industry Team Members	Mike Miller (Southern Company), Miodrag Djukanovic (MidAmerican Energy) and Kolluri Sharma (Entergy)
Project Period	December 2003 to April 2005
Status	Final report available in the 2005 Reports Folder . PSERC Document 03-26.

2.10 Optimal Placement of Phasor Measurement Units for State Estimation (S-23G)

Project Name	Optimal Placement of Phasor Measurement Units for State Estimation (S-23G)
Summary	This project is concerned about optimal placement of phasor measurement units in order to make a power system fully observable.
Research Stem	Systems
Academic Team Members	Lead: Ali Abur, TAMU Team members: Ali Abur, TAMU
Industry Team Members	Warren Wu (TVA) and Lisa Beard (TVA)
Start and End Dates	June 2004 to July 2005
Status	Final report (05-58) available in the 2005 Reports Folder .

3 Current Systems Projects

3.1 Enhanced State Estimators (S-22)

Summary:	This is a research project on enhancements for power system state estimators. The main objective is to increase accuracy and robustness to the point that operators will have a high level of confidence in the use of these software tools. A second objective is to utilize automated features for self-tuning and improved models for high accuracy.
Research Stem:	Systems
Academic Team Members:	Lead: Ali Abur (Northeastern University; abur@ece.neu.edu; 617-373-3051) Team: G. T. Heydt (Arizona State University), A. P. S. Meliopoulos (Georgia Tech)
Industry Team Members:	Dale Krummen (AEP), Jay Giri (ESCA), Jerome Ryckbosch (RTE-France), Ram Adapa (EPRI), Dr. Choo (KEPRI), Peter Hirsch (EPRI)
Start and End Dates:	June 2004 to June 2006.

3.2 Optimal Allocation of Static and Dynamic VAR Resources (S-24)

Summary:	Develop methodologies for optimal selection and placement of static and dynamic VAR resources in a system. Criteria for determining the optimal level and location of dynamic VAR sources will be investigated and proposed including voltage recovery requirements, protective relay response, voltage stability margin requirements and other. A methodology to optimize the amount and placement of static and dynamic VAR sources will be developed that satisfies the criteria. The issue of modeling load dynamics will be addressed and methodologies for accounting for the variability of loads and their dynamics will be developed.
Research Stem:	Systems
Academic Team Members:	Lead: A. P. Meliopoulos (GIT, sakis.meliopoulos@ece.gatech.edu , 404-894-2926) Team Members: V. Ajjarapu (ISU, vajjarap@engr.iastate.edu), Jim McCalley (ISU, jdm@iastate.edu), Ian Hiskens (UW, Madison, hiskens@engr.wisc.edu), V. Vittal (ASU, vijay.vittal@asu.edu)
Industry Team Members:	Sharma Kolluri/Floyd Galvan (Entergy), Don Morrow (ATC), Jiuping Pan, ABB, Mike Ingram/Lisa Beard (TVA), Raymond Vice (Southern Co.), Ali Chowdury (Mid-American), John Dalton (Duke), Dale Krummen (AEP), Baj Agrawal (APS), Aty Edris (EPRI)
Start and End Dates:	June 1, 2005 to August 31, 2007.

3.3 Effective Power System Control Center Visualization (S-25)

Summary:	Electric power systems are characterized by an overwhelming amount of data. The goal of this project is the continued development of better visualization techniques to help glean useable information from this data with an emphasis on control room applications.
Research Stem:	Systems
Academic Team Members:	Lead: Tom Overbye (U of Illinois, overbye@ece.uiuc.edu , 217-333-4463) Team members: Sakis Meliopoulos (Georgia Tech, sakis.meliopoulos@ece.gatech.edu) Esa Rantanen (replacing Doug Wiegmann) (U of Illinois, dwiemann@uiuc.edu)
Industry Team Members:	PJM (Ken Huber, Jianzhong Tong), TVA (Lisa Beard), Exelon (David Schooley), ATC (Don Morrow), AEP (Dale Krummen), PowerWorld (Jamie Weber and Ray Klump), Entergy (Floyd Galvan), AREVA (Jay Giri), Southern Company (?), Powertech/BCTC (Kip Morison), ISO New England (Eugene Litvinov), Khoi Vu (ABB), Paulette Kaptain (WAPA), Pei Zhang (EPRI)
Start and End Dates:	June 1, 2005 to August 31, 2007.

3.4 A Tool for On Line Stability Determination and Control for Coordinated Operating between Regional Entities Using PMUs (S-27)

Summary:	This project deals with the development of an analytical tool to determine <i>on line</i> transient stability limits using phasor measurements from PMUs and to coordinate operating criteria between widely dispersed regional operating areas.
Research Stem:	Systems
Academic Team Members:	Lead: Vijay Vittal (Iowa State University, vijay.vittal@asu.edu, 515-294-8963) Team members: G. T. Heydt (Arizona State University, heydt@asu.edu) A. P. Meliopoulos (Georgia Tech University, sakis@comcast.net)
Industry Team Members:	Sharma Kolluri – Entergy Corporation Navin Bhatt – AEP Lisa Beard – TVA Peter Hirsch – EPRI Kip Morison – Powertech Labs
Start and End Dates:	June 1, 2005 to August 31, 2007.

3.5 Detection, Prevention and Mitigation of Cascading Events – Prototype Implementations (S-29)

Summary:	<p>The project aims to implement the algorithms developed in the recently ended PSERC project (S19) on cascading events to the power systems of the collaborating PSERC companies. The algorithms are based on wide-area PMU measurements as well as raw data from IED's, together with model based simulations. They address three subproblems:</p> <ul style="list-style-type: none"> a) Detection of major disturbances and protective relay operations leading to cascading events. b) Wide area measurement based remedial action. c) Adaptive islanding with selective underfrequency load shedding <p>The proposed project is a two-year continuation of S19, solely focused on the prototype implementation of the novel algorithms that have been previously developed in the S19 project.</p>
Research Stem:	Systems (and T&D)
Academic Team Members:	<p>Lead: Mani V. Venkatasubramanian (Washington State University, Pullman, WA, mani@eecs.wsu.edu, 509-335-6452)</p> <p>Team members: Mladen Kezunovic (Texas A&M, College Station, TX, kezunov@ee.tamu.edu) Vijay Vittal, (Arizona State University, Tempe, AZ, vijay.vittal@asu.edu)</p>
Industry Team Members:	Galvan Floyd (Entergy), Lisa Beard (Tennessee Valley Authority), Jay Giri (Areva T&D), Kip Morrison (Powertech Labs), Navin Bhatt (American Electric Power), Richard Young (American Transmission Company), Ram Adapa (Electric Power Research Institute), Tae-Kyun Kim and Jeong-Hoon Shin (Korean Electric Power Research Institute).
Start and End Dates:	June 1, 2006 - August 31, 2008

4 Completed T&D Projects

4.1 Enhanced State Estimation via Advanced Substation Monitoring (T-9)

Project	Enhanced State Estimation via Advanced Substation Monitoring (T-9)
Summary	This project concerns innovative methods for using new types of analog and digital measurements at substations for improving state estimation. The new measurements are provided by a new generation of digital relays and other IEDs. The project will investigate a range of state estimation issues and will develop a prototype computer program that will be used to illustrate the effectiveness of the developed methods using real-life scenarios.
Research Stem	Transmission and Distribution Technologies
Academic Team Members	Ali Abur (Texas A&M – lead), Mladen Kezunovic (Texas A&M) and A.P. Meliopoulos (Georgia Tech)
Industry Team Members	ABB ETI, ABB NM, Entergy Services, Mitsubishi ITA, Reliant Energy HL&P and Oncor
Project Period	September 1, 2000 to August 31, 2002
Status	Final report available in 2002 Reports folder. PSERC Document 02-48.

4.2 Power System Monitoring Using Wireless Substation and System-Wide Communications (T-11)

Project	Power System Monitoring Using Wireless Substation and System-Wide Communications (T-11)
Summary	This project investigates wireless power system monitoring applications that communicate real-time data from substations. Research will be conducted on issues associated with data acquisition and collection, and algorithms for system-wide communications using mobile agents. A particular application, monitoring circuit breaker operations for maintenance decision-making, will be studied.
Research Stem	Transmission and Distribution Technologies
Academic Team Members	Mladen Kezunovic (Texas A&M – lead), Costas Georghiades (Texas A&M) and Rahmat A. Shoureshi (Colorado School of Mines)
Industry Team Members	ABB ETI, ABB NM, Entergy Services, Mitsubishi ITA, Reliant Energy HL&P and Oncor
Project Period	September 1, 2000 to August 31, 2002
Status	Final reports available in 2002 Reports folder. PSERC Documents 02-46 and 02-47.

4.3 Enhanced Reliability of Power System Operation Using Advanced Algorithms and IEDs for On-Line Monitoring (T-17)

Project name	Enhanced Reliability of Power System Operation Using Advanced Algorithms and IEDs for On-Line Monitoring (T-17)
Summary	Introduction of Intelligent Electronic Devices (IEDs) in power systems enables new monitoring applications. This project introduces new fault location, substation state estimation and wireless communication applications.
Research Stem	T&D Technologies
Academic Team Members	Mladen Kezunovic (Texas A&M-lead) Co-Leader: Ali Abur (Texas A&M) Sakis Meliopoulos (Georgia Tech) and Rahmat Shoureshi (Colorado School of Mines)
Industry Team Members	TVA (M. Ingram), Reliant Energy HL&P (D. Sevcik), ABB (M. Subramanian), AEP (D. Krummen), Entergy (L. Priez), Mitsubishi (D. Wong), Tri-State G&T Association (A. Mander), TXU (J. Bell), WAPA (P. Kaptain)
Project Period	June 1, 2002 to August 31, 2005
Status	Final report available in the 2005 Reports Folder . Parts I and II in PSERC Documents 05-56 and 05-57.

4.4 Automated Integration of Condition Monitoring with an Optimized Maintenance Scheduler for Circuit Breakers and Power Transformers (T-19)

Project Name	Automated Integration of Condition Monitoring with an Optimized Maintenance Scheduler for Circuit Breakers and Power Transformers (T-19)
Summary	Cost-effective transmission equipment maintenance requires on-going integration of information from multiple sources. This project will develop a real-time software solution that performs this information integration automatically.
Research Stem	T&D Technologies
Academic Team Members	Jim McCalley (Iowa State, EE-lead) Mladen Kezunovic (Texas A&M, EE), Chanan Singh (Texas A&M, EE), Vasant Honavar (Iowa State, Computer Science)
Industry Team Members	Mid American Energy (Andrew Geest), CenterPoint Energy (Don Sevcik), TXU Electric Delivery (Jim Bell)
Project Period	June 1, 2002 to August 31, 2005
Status	Final report available in the Reports Member Viewing Only Folder . PSERC Document 06-04.

4.5 Performance Assessment of Advanced Digital Measurement and Protection Systems (T-22)

Project Name	Performance Assessment of Advanced Digital Measurement and Protection Systems (T-22)
Summary:	The objective of this proposal is to provide quantitative comparison between an integrated measurement and protection solution based on optical CT and PT connected to the protection system with a digital link and the traditional magnetic CT and PT supplying analogue signals to the traditional measurement and protection system
Research Stem:	T&D Technology
Academic Team Members:	Lead: George G. Karady (ASU) Co-PI: Mladen Kezunovic (TAMU)
Industry Team Members:	American Electric Power (Dale Krummen), NxtPhase (Farnoosh Rahmatian), TXU Electric Delivery (Kevin Allen), CenterPoint Energy (Don Sevcik), Salt River Project (Don Pelley), WAPA (Lane Cope), Duke Energy, TVA (Mike Ingram), Exelon (James Crane), IREQ (Luc Audette)
Start and End Dates:	January 2004 to December 2005
Status	Final report in preparation.

5 Current T&D Stem Projects

5.1 Massively Deployed Sensors (T-31)

Summary	The main objective of this proposed project is to utilize a large number of distributed sensors, including non-conventional sensors and innovative instrumentation, located in the power system by some prioritized strategy that includes metrics associated with system observability, power usage, enhancement of communication capabilities, and size of data for operations and enhanced operational decision making, to detect potential intrusions and sabotage, and for post-mortem studies after failures.
Research Stem	T&D Technologies
Academic Team Members	Lead: ASU, G. Heydt, heydt@asu.edu, 480 965 8307 Team members: Wichita State University, W. Jewell, ward.jewell@wichita.edu, 316 978 6340 P. K. Sen, Colorado School of Mines, psen@mines.edu, 303 384 2020
Industry Team Members	David Allen, AREVA T&D, david.allen@areva-td.com Jay Giri ,AREVA T&D, jay.giri@areva-td.com, 425 739 3522 Ali Chowdhury, MidAmerican, aachowdhury@midamerican.com, 563-333-8142 Richard Loyd, Steel Tube Institute, dickonel@aol.com Art Mander, Tri-State G&T, amander@tristategt.org, 303 452 6111 Robert Saint, NRECA, robert.saint@nreca.org, 703 907 5863
Start and End Dates	August 15, 2006 - August 31, 2008

5.2 Integration of Substation IED Information into EMS Functionality (T-32)

Summary	Currently large amounts of information are collected by Intelligent Electronic Devices (IEDs) at the substation level. Beyond the traditional SCADA data collected by RTUs, very little of other IED information is integrated into the current EMS solutions. The goal of the project is to investigate the potential benefits of integrating the substation IED information, beyond RTU data, into the EMS.
Research Stem	T&D Technologies
Academic Team Members	Project Leader: Mladen Kezunovic (TAMU, kezunov@ee.tamu.edu, 979-845-7509) Team member: Tom Overbye (UIUC, Overbye@ece.uiuc.edu)
Industry Team Members	Jim Stoupis (ABB), Ron Allen (AEP), David Allen (AREVA), John G. Dalton (Duke Power), Bhavin Desai (EPRI), Steven Hedden (Exelon), Ali A. Chowdhury (MidAmerican), Mark J. Laufenberg (Power World), Paul M. Skare (Siemens), Bruce Rogers (TVA), Byron Reid (TXUD)
Start and End Dates	June 1, 2006 - August 31, 2008