Power Systems Engineering Research Center

PSERC Projects Ending in 2017

Advanced Cyber-Physical Analysis for Smart Grid Distributed ICT and IED Resources at RTE France (S-63G)

Summary	The availability of a vast number of substation IEDs and distributed computational resources offers great potential for enhancing the smart grid. However, the distributed computing infrastructures in utilities today are nowhere near adequate to exploit this potential, being decades behind those in other industries. This project will lead to several technologies and tools, and analyze others, to help utilities and vendors to develop next- generation cyber-physical infrastructure using distributed ICT and IED resources. The problems addressed by this project, as well as the software released, will be widely applicable to utilities, ISOs, and vendors.
Academic Team	Project Leader: Dave Bakken (Washington State Univ., bakken@wsu.edu) Team members: Anurag Srivastava (Washington State Univ.)
Industry Advisors	Daniel Arjona (Idaho Power); Patrick Panciatici (RTE France); Juan Castaneda (SCE)

Monitoring and Maintaining Limits of Area Transfers with PMUs (S-64)

Summary	We will develop practical methods based on PMUs to detect and act on conditions in which transfer of power through areas of the power system should be curtailed to satisfy thermal line limits and small signal stability limits. Closed loop controls for robust stability will also be developed. The larger objective is to combine measurements with physical network models to turn PMU data into actionable advice for operators to improve the management of bulk power transfers and control instabilities.
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Industry Advisors	Guru Pai (Alstom Grid); Anil Jampala (Alstom Grid); Baj Agrawal (APS); Giuseppe Stanciulescu (BC Hydro); Evangelos Farantatos (EPRI); Navin Bhatt (EPRI); Mahendra Patel (EPRI); Dave Schooley (Exelon/ComEd); Alan Engelmann (Exelon/ComEd); Santosh Veda (GE Global Research); Naresh Acharya (GE Global Research); Chaitanya Baone (GE Global Research); Orlando Ciniglio (Idaho Power); Milorad Papic (Idaho Power); Slava Maslennikov (ISONE); Ed Muljadi (NREL); Saman Babaei (NYPA); Paul Runana (WAPA)

Mitigating Adverse Impacts of Negative Damping Induced by Wind Generators on Power Grid Dynamics (S-69G)

Summary	Integration of wind energy units to the power system introduces a new set of dynamics, including negative damping. This project seeks to study and characterize these dynamics and design controllers to mitigate the adverse impacts.
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Industry Advisors	Saman Babaei (NYPA); Alan Ettlinger (NYPA)

Setting-less Protection: Field Demonstrations (T-56G)

Summary	In the past few years, Georgia Tech and EPRI have been developing the setting-less protection technology. This technology has been demonstrated in the laboratory. Last year a field demonstration project was initiated involving three PSERC members (EPRI, NYPA and GE), sponsored by NYSERDA. Work was also initiated towards the development of centralized substation protection systems. The proposed project provides support for the field implementation and validation of the settingless protection relay on one of the PSERC members and it is continuation of the work from the previous year.
Academic Team	Project Leader: Sakis Meliopoulos (Georgia Tech, sakis.m@gatech.edu)
Industry Advisors	Paul Myrda (EPRI); Bruce Fardanesh (NYPA); George Stefopoulos (NYPA); Feliks Karchemskiy (PG&E); James Hudson (SRP); Manish Patel (Southern Company)

RTE DSE-Protection Demonstration (T-59G)

Summary	Georgia Tech and EPRI have been developing the Dynamic State Estimation based protection method (a.k.a. setting-less protection). This technology has been demonstrated in the laboratory and also a demonstration project with NYPA under NYSERDA sponsorship is in progress. The objective of the proposed project is to demonstrate the technology on the digital substation that RTE is developing. A DSE based relay will be developed for the protection of RTE's digital substation, factory tested at the Georgia Tech laboratory and it will be installed on RTE's digital substation.
Academic Team	Project Leader: Sakis Meliopoulos (Georgia Institute of Technology, sakis.m@gatech.edu
Industry Advisors	Patrick Panciatici,Thibault Prevost, Volker Leitloff, Aurelien Watare, Christian Guibout, RTE

PSERC Projects Ending in 2018

Robust and Decentralized Operations for Managing Renewable Generation and Demand Response in Large-Scale Distribution Systems (M-35)

Summary	The distribution system is becoming more complex and active. Distribution system operators may face a portfolio of an extremely large number of devices including distributed generators (DG), demand response (DR) resources, storage devices, and emerging proactive customers with various resources (electric vehicles, smart appliances, rooftop PVs, TCLs). Many of these devices may exhibit stochastic supply or consumption patterns. A portfolio of these devices can significantly increase the flexibility of the distribution system for system balancing and congestion management. The goal of this project is to develop new operational models and algorithms to efficiently operate such a large portfolio of controllable but uncertain resources in an active distribution system with the aim to increase flexibility and reliability of both distribution and transmission systems. The proposed models will provide the industry with computational tools to manage various types of uncertainties through robust optimization techniques and a mixture of centralized and decentralized control schemes in order to improve scalability of the operational algorithms. The project will also explore efficient solution methods for incorporating unbalanced multi-phase power flow models in the proposed scheduling algorithms in order to accurately model the distribution system.
Academic Team	Project Leader: Andy Sun (Georgia Tech, andy.sun@isye.gatech.edu, 404-385-7574) Team member: Duncan Callaway (U.C. Berkeley, dcal@berkeley.edu)
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Analysis of Power System Operational Uncertainty from Gas System Dependence (M-36)

Summary	The heavier reliance on natural gas for electricity generation raises increasing power system security concerns because gas-fueled generators may be subject to gas supply shortages and/or high spot market prices. While under FERC directives the industry has undertaken appropriate steps to better align the gas supply plans with the forecast electricity loads, the gas supply issue has become a challenging uncertainty that must be considered explicitly in power system operations. The goals of this project are to analyze the impacts of the uncertainty created by gas supply vulnerabilities and to assess the risks that emanate from the unit commitment/dispatch schedules. The interpretation of the analysis and the risk assessment results with intuitively meaningful presentation of the information will allow the formulation of appropriate strategies to address the issues associated with the gas supply/cost uncertainty. Study of the impacts of the gas uncertainty on the grid operational flexibility (GOF) for systems with deep penetration of renewable resources will allow a practical assessment of the extent of GOF change due to gas shortage issues and the identification of GOF shortfalls that can result in power system insecurity.
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Leveraging Conservation Voltage Reduction for Energy Efficiency, Demand Side Control and Voltage Stability Enhancement in Integrated Transmission and Distribution Systems (S-70)

Summary	We propose a comprehensive framework that assesses energy saving, demand reduction and stability enhancement potential of conservation voltage reduction (CVR). A new algorithm based on load modeling is developed to assess real-time real/reactive load-reduction effects of CVR. A co-simulation framework for transmission and distribution systems is proposed to investigate the impacts of CVR on voltage stability margins of transmission systems. The identified time-varying load models are integrated into the co-simulation framework to capture CVR effects. The coordination between energy-oriented and stability-oriented CVR will be studied. The mutual impacts between voltage reduction and voltage control of DGs will also be investigated. The combination of these approaches will assist utilities to select feeders to implement voltage reduction, perform cost/benefit analyses, reduce the stress of transmission systems, and improve the operation of integrated transmission and distribution systems.
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Real-time Synchrophasor Data Quality Analysis and Improvement (S-71)

Summary	This project aims at developing strategies for real-time data quality management of streaming PMU data. With the recent impetus towards design and adoption of synchrophasor-based applications in the power industry, there is an urgent need to develop online techniques for detecting, analyzing, and mitigating bad as well as missing data in real-time streams. In this project, we will build a systematic online framework for identifying and handling typical data quality issues such as clock errors, transducer errors and network delays. Based on the synchrophasor data's spatio-temporal correlations, the proposed approach is capable of identifying bad data during both normal and fault-on conditions. Real-world synchrophasor data as well as synthetic dynamic grid models will be used to differentiate the root causes of data quality issues and to validate the proposed strategies.
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Attack-Resilient and Secure EMS: Design, Algorithms, Operational Protocols, and Evaluation (S-72)

Summary	The modern electric grid is a highly automated cyber-physical system (CPS) and is increasingly dependent on cyber-based automation systems for various monitoring, control, protection, and market functions. The DOE, DHS, and NERC have identified concerns that the grid is vulnerable to sophisticated coordinated cyber-attacks. This leads to the following fundamental question: can reasonably realistic (i.e., attackers with limited capabilities) cyber-attacks be modeled and tested on electric power system (EPS) simulation platforms to: (a) evaluate attack severity and consequences and (b) evaluate resiliency of energy management systems (EMSs) to such attacks? The goal of the proposed research is three-fold: (i) identify credible threats and develop attack-resilient control algorithms (countermeasures) that can be modularly integrated into energy management systems (EMSs); (ii) develop a realistic software-hardware simulation testbed comprised of EMS software platform (ASU) and a hardware SCADA system in conjunction with a power system simulator (ISU); and (iii) use the integrated software-hardware testbed to evaluate credible threats and countermeasures.
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Functional assessment of DFIG and PMSG-based wind turbines for grid support applications (S-73G)

Summary	The specific objectives of this project are to i) investigate the capability of doubly-fed induction generator (DFIG) and permanent-magnetic synchronous generator (PMSG)-based wind turbine systems to provide reactive power support at low wind speed and/or in cases of voltage drop, ii) develop new reactive power control techniques for wind turbines, iii) assess the suitability of using DFIGs to regulate frequency without energy storage systems, and iv) explore the possibility of DFIG inertia sustaining network voltage and frequency immediately following fault occurrence and before fault detection, in systems with low physical inertia and high wind penetration. Experiments will validate proposed theories.
Academic Team	Project Leader: Zhaoyu Wang (Iowa State University, wzy@iastate.edu)
Industry Advisors	Thibault Prevost (RTE), Florent Xavier (RTE)

Improving Voltage Stability Margin Estimation through the use of HEM and PMU Data (S-77G)

Summary	Voltage stability security is best ensured by complementing some form of system simulation with real-time measurements. Both approaches have their strong and weak points. For example, system simulations are able to predict the effects on voltage stability margin of contingencies while real-time-measurement-based Thévenin equivalents are not hampered by any erroneous data that may be part of the system model. Thévenin equivalent approaches however work well on small systems but fail on large systems. The objective of this proposal is to develop a set of theoretically-based rules for developing and using Thévenin-based equivalent approaches for estimating voltage stability margin on large systems and then demonstrate the effectiveness of these techniques on larger systems or understand their limitations. We also propose to develop a set of nonlinear equivalents, establish their properties and determine their fitness for use in measurement-based voltage-stability assessment approaches..
Academic Team	Project Leader: Daniel Tylavsky (Arizona State University, tylavsky@asu.edu)
Industry Advisors	Di Shi, Zhiwei Wang, Jidong Chai, Xiaohu Zhang, Xi Chen, Zhe Yu, Wendong Zhu, Xinan Wang, Janet Zhang (GEIRI North America)

Efficient modeling of modular multilevel converters for fast simulation of large-scale MMC-HVDC embedded power systems (S-78G)

Summary	Modular multilevel converters (MMCs) have become the most attractive multilevel converter topology for voltage-sourced converter high-voltage direct current (VSC-HVDC) transmission systems. The salient features of MMCs include: 1) modularity and scalability to meet any voltage level by stacking up additional numbers of SMs without increasing topology complexity, 2) inherent redundancy and fault-tolerance capability to improve reliability, 3) high efficiency suitable for high-power applications, and 4) high power quality and low filter and transformer cost due to filter-free and transformerless applications by realization of high-level converters. With the increasing number of MMCHVDC systems embedded into the AC grid, performance of the present power system can be dramatically improved, including stability, reliability, capacity, and efficiency. However, MMCs' applications in power systems are restricted due to the challenge to efficiently and accurately model a variety of such power electronics-based components for large-scale power system analysis, modeling, and simulation. In this project, the PI proposes to investigate and develop new generalized high-efficiency modeling techniques, with covering various submodule (SM) circuits and MMC topologies, which can be used and integrated in electromagnetic transient (EMT) power system simulation software packages and real-time hardware-in-the-loop (HIL) simulation platforms for large-scale MMCs-embedded power system analysis and simulation.
Academic Team	Project Leader: Jiangchao Qin (Arizona State University, jqin@asu.edu)
Industry Advisors	Di Shi, Xi Chen, Zhiwei Wang, Xi Chen (GEIRI North America)

Input-Output Properties of the Power System Swing Dynamics: Identification, Model Reduction, and Controller Designs (S-79G)

Summary	Variability in the bulk power transmission network introduced by the integration of intermittent renewables, among other reasons, is necessitating new wide-area controls for managing oscillations and transients. At the same time, new technologies including synchrophasors and power electronics are enabling implementation of fast wide-area controls. The evaluation and design of these controls requires understanding input-output processes---and specifically the presence or absence of nonminimum-phase zeros---in the power network¿s swing dynamics. In a previous PSERC project, we have demonstrated how nonminimum-phase dynamics are tied to the topology and input-output channel location, generation profile, and damping in the network, as well as the specifics of deployed controllers (e.g. HVDC modulation). Further, the project has demonstrated that appropriate modeling of nonminimum-phase behaviors is crucial for many aspects of control/analysis of fast dynamics, including model reduction, disturbance analysis, and control design. This new project will be focused on developing the methods necessary for: 1) model-based quantitative analysis of nonminimum-phase dynamics, 2) model reduction to preserve zero structure, 3) wide-area controller design, and 4) estimation of transfer function zeros from synchrophasor measurements. These design tasks will be achieved by drawing on the topology-based results developed in the first project year, as well as structural transformations and control design techniques that account for a linear system¿s zero dynamics. The investigators will also undertake application of the methods to a model of the France-Spain power network.
Academic Team	Project Leader: Sandip Roy (Washington State University, sroy@eecs.wsu.edu)
Industry Advisors	Patrick Panciatici (RTE)

Life-cycle Management of Mission-Critical Systems through Certification, Commissioning, In-Service Maintenance, Remote Testing, and Risk Assessment (T-57HI)

Summary	The life-cycle management of mission critical systems requires tools and methodologies that are not readily available. For example, no standard tools for certification, commissioning, in-service maintenance, and risk assessment are available for synchrophasors used for Wide Area Protection, Monitoring and Control; and Special Protection Schemes. This project will deliver such tools for: • Device and system testing of synchrophasor systems, substation measurement equipment, etc. • Calibration and field testing equipment for in-service maintenance • Remote testing and detection of device failures and data management architecture problems • Visualization to track the state of mission-critical systems and to help with maintenance and repair.
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Power Electronics to Improve the Performance of Modern Power Systems: Case Study on Partially Rated Solid-State Transformers (T-58)

Summary	As the power industry prepares to update distribution and transmission assets that are reaching the end of their lifetime, it is prudent to consider alternatives and likely new applications enabled by technological advances. Among these technologies are power electronics solutions, especially in the light of recent and / or potential advances in technology and material science (e.g., the advent of wide bandgap devices). We propose a two-pronged research effort: (i) an explorative study on the requirements of power electronics (e.g., ratings, basic impulse level, lifetime, and maintenance) and necessary improvements in this technology to enable its use in power systems and (ii) an application design study of partially rated power electronics-enabled transformers for truck-mounted and load tap changer applications.
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PSERC Projects Ending in 2019

Development of Expansion Planning Methods and Tools for Handling Uncertainty (M-37)

Summary	Appropriately addressing uncertainty has been recognized as a major challenge for generation and transmission planning. Most existing planning models and tools become computationally intractable when considering a large number of scenarios; however, a small set of scenarios often fail to include the low probability and high impact ones that are critical to ensure the resiliency of the transmission network. We propose to develop a new method for generating a small number of high quality scenarios to help existing expansion planning models and tools to produce more resilient solutions. The effectiveness of the new method will be validated using existing planning tools on realistic case studies
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Coordination Mechanisms for Seamless Operation of Interconnected Power Systems (M-38)

Summary	Concerted coordination among grid operators (GOs) such as ISOs/RTOs/PMAs in an interconnected power system is imperative to fully exploit the spatial and temporal diversity of renewable wind and solar resources, as well as other grid resources. An effective coordination mechanism needs to respect practical limitations on information exchange, be harmonized with existing market structures that GOs operate and/or facilitate within the areas they control, and be able to explicitly incorporate the impacts of uncertainty under deepening penetration of renewable resources. This project broadly aims to design and analyze the performance of such coordination mechanisms and to construct a unified framework to quantify their benefits. In addition, we adapt the proposed mechanisms in the bulk power systems to coordinate among neighboring microgrids in the emergent distribution network market environment.
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Synchrophasor – Data Analytics for a More Resilient Electric Power System (S-74)

Summary	The aim of this proposal is to develop wide area measurement systems (WAMS)-based tools and algorithms for monitoring, protection, and control of the electric power system. The specific topics of focus are: faster islanding detection schemes and online asset health monitoring (monitoring application); combating cyber-attacks by developing data analytics algorithms that enhance system resiliency (protection application); increasing situational awareness when system has large penetration of renewable generation (control application). Synthetically-generated simulated data will be used to test the tools while synchrophasor data obtained from the field will be used to validate the tool's performance for real-world applications.
Academic Team	Project Leader: Anamitra Pal (Arizona State University, Anamitra.Pal@asu.edu), Team Members: Lalitha Sankar (Arizona State University, lsankar@asu.edu) Christopher DeMarco (University of Wisconsin-Madison, cdemarco@wisc.edu)
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Reliability Evaluation of Renewable Generation Integrated Power Grid including Adequacy and Dynamic Security Assessment (S-75)

Summary	Probabilistic methodologies are needed for reliability assurance in the emerging power grids with increasing penetration of renewable resources. Most of the probabilistic methodologies have focused on the adequacy issues. Some work has also been done on the probabilistic stability including, small signal and transient stability. The objective of this proposal is to integrate reliability into a single frame work including adequacy and transient stability evaluation and develop computationally tractable methods to achieve this objective.
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Modeling, Control, and Protection of Multi-Terminal Direct-Current Transmission for Improving Power Grid's Performance (S-76)

Summary	High Voltage DC (HVDC) transmission is a long-standing technology with many installations around the world. Over the past few years, significant breakthroughs in the Voltage-Sourced Converter (VSC) technology along with their attractive features have made the HVDC technology even more promising in providing enhanced reliability, functionality, reducing cost, and power losses. Concomitantly, significant changes in generation, transmission, and loads such as (i) integration and tapping renewable energy generation in remote areas, (ii) need for relocation or bypassing older conventional and/or nuclear power plants, (iii) increasing transmission capacity, and (iv) urbanization and the need to feed the large cities have emerged. These new trends have called for Multi-Terminal DC (MTDC) systems, which when embedded inside the AC grid, can enhance stability, reliability, and efficiency of the present power grid. Amid the optimism surrounding the MTDC grids, the following fundamental research questions must be addressed. First, what control strategies are required to operate the MTDC converter stations? Secondly, how will the MTDC grid interact with its surrounding AC system and what kind of services (e.g., frequency support and power oscillation damping) can it provide? Thirdly, how would a converter station outage impact the operation/stability of the system? Lastly, how can DC faults be detected, identified, and cleared? To this end, a multi-pronged research effort is proposed: (i) to development of suitable dynamic models of the MTDC systems which can be efficiently solved together with the AC systems; (ii) design of advanced control strategies enabling the MTDC systems to support the resulting hybrid AC/DC systems; and (iii) development of strategies for DC fault detection, identification, and protection of MTDC systems.
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Assessing the Reliability of Power Grid with Flexible Demand Response and other Disrupting Factors (S-80G)

Summary	Probabilistic methodologies are needed for reliability assurance in the emerging power grids with increasing penetration of renewable resources and enhanced information technologies providing two way communications with the loads. Most of the probabilistic methodologies for assuring reliability have focused on the generation side. Some work has also been done on the demand side but it is based mostly on deterministically shaving the peak or other portions of the load. This research will focus on understanding the fundamental issues involved in the use of responsive demand to improve reliability and reduce the reserve as well the storage in the presence of variable energy sources. More realistic models of contingency responsive demand and generation will be developed.
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Oscillation Monitoring and Control of the RTE Power System Using Synchrophasors (S-81G)

Summary	Recent advances in design of fast oscillation monitoring algorithms have paved the way for real-time detection and analysis of electromechanical oscillations from wide-area synchrophasor measurements in large power interconnections. The oscillations if left unmitigated can lead to unwanted tripping of transmission lines and generators that could cascade into devastating blackouts. Oscillation monitoring algorithms developed at Washington State University have previously been implemented and tested in North American power grid and in India. In this project, we will study oscillation phenomena in the RTE portion of the European power grid by using available synchrophasor data. Suitability of ambient versus ringdown analysis algorithms for analyzing recent oscillation events in RTE will be investigated. Oscillation analysis results using transmission level PMUs will be compared with corresponding results using distribution level Phasor Measurement Units (PMUs). The effectiveness of the oscillation algorithms will be tested and improved by using simulated PMU data from dynamic models of the RTE system wherein the expected answers are known from small-signal analysis of the dynamic models. New oscillation analysis and control algorithms will be developed in the project as needed in collaboration with RTE to address the oscillation issues in RTE.
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Framework to Analyze Interactions between Transmission and Distribution (T&D) Systems with High Distributed Energy Resource (DER) Penetrations (T-60)

Summary	This project aims at developing an integrated T&D system analysis framework to study and mitigate the impacts of high penetrations of DERs. A coupled T&D analysis framework is developed through co-simulation approach. The framework utilizes legacy software to separately solve the decoupled models. The T&D interactions are captured by exchanging network solutions at the point of common coupling (PCC). The co-simulation approach adds modularity to the analysis and helps in achieving speed and scalability. The framework is utilized to understand and mitigate the impacts of high DER penetrations. Power quality issues which are otherwise difficult to model are studied, and mitigation schemes are proposed. Finally, the utility of DERs as an active participant in system operations is explored.
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