

Collaborative Industry/University Research At PSERC

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Arizona State University

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JST-NSF-DFG-RCN

**Workshop on Distributed Energy
Management Systems**

**Future Power System Architectures and
Control Paradigms**



PSERC Overview

- NSF Industry/University Cooperative Research Center: lead university at Arizona State Univ.
- Collaborative, Industry-Supported, Multi-disciplinary Research: Power Systems, T&D Technologies, Power Markets and Policies
- Also Federally-Supported Research
 - Consortium for Electric Reliability Technology Solutions
 - Future Grid for Enabling Sustainable Energy Systems
- 37 industry members, 13 universities, 50+ faculty (many more “in the wings”), 60+ grad students

Collaborating Universities and Site Directors

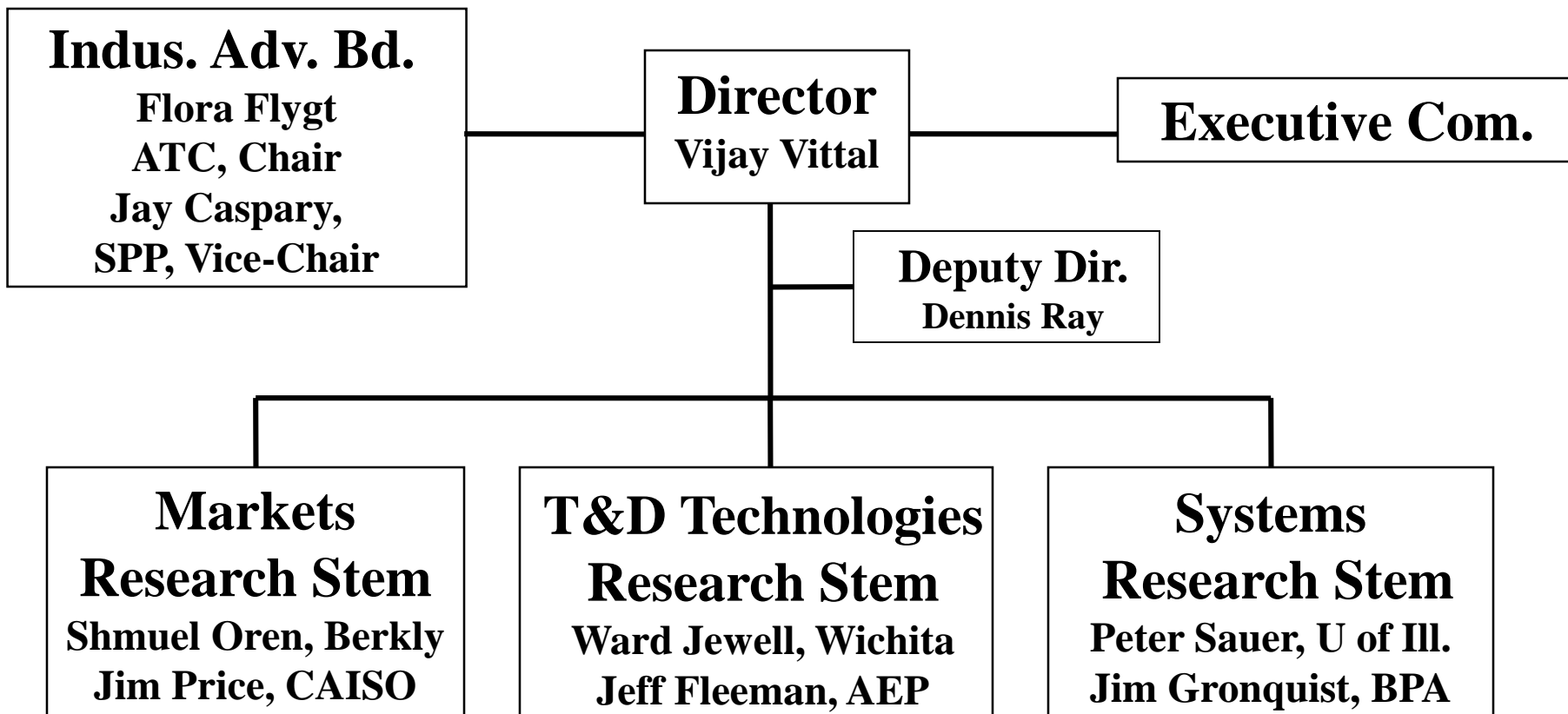
- **Arizona State University** - Gerald Heydt
- **University of California at Berkeley** - Shmuel Oren
- **Carnegie Mellon University** - Marija Ilic
- **Colorado School of Mines** - P.K. Sen
- **Cornell University** - Lang Tong
- **Georgia Institute of Technology** - Sakis Meliopoulos
- **Howard University** - James Momoh
- **University of Illinois at Urbana** - Peter Sauer
- **Iowa State University** - Venkataramana Ajjarapu
- **Texas A&M University** - Mladen Kezunovic
- **Washington State University** - Anjan Bose
- **University of Wisconsin-Madison** - Chris DeMarco
- **Wichita State University** - Ward Jewell

Current Industry Members

ABB
American Electric Power
American Transmission Co.
ALSTOM Grid
Arizona Public Service
BC Hydro
Bonneville Power Admin.
California ISO
CenterPoint Energy
Duke Energy
EPRI
Exelon
GE
FirstEnergy
Institut de recherche d'Hydro-Québec
(IREQ)
ISO New England
ITC Holdings
Lawrence Livermore National Lab

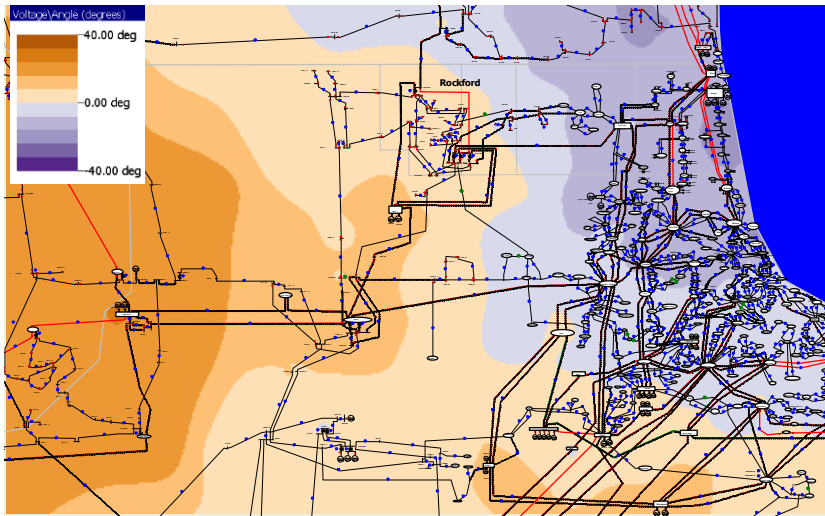
Midcontinent ISO
Mitsubishi Elec. Research Lab
NASA
National Renewable Energy Lab.
National Rural Elec. Coop. Assn.
New York ISO
New York Power Authority
Pacific Gas and Electric
PJM Interconnection
PowerWorld Corp.
RTE (France)
Salt River Project
Southern California Edison
Southern Company
Southwest Power Pool
TVA
Tri-State G&T
U.S. DOE
Western Area Power Admin.

Our Organization

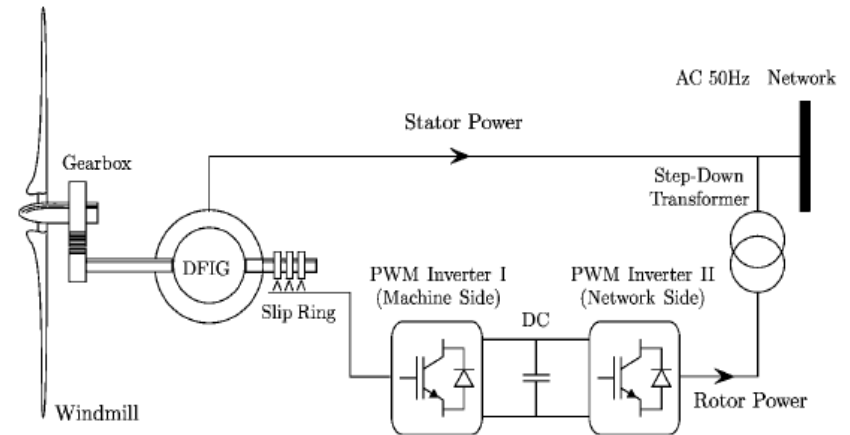


Systems Research Stem

Systems research focuses on efficient and reliable operation of complex and dynamic power systems



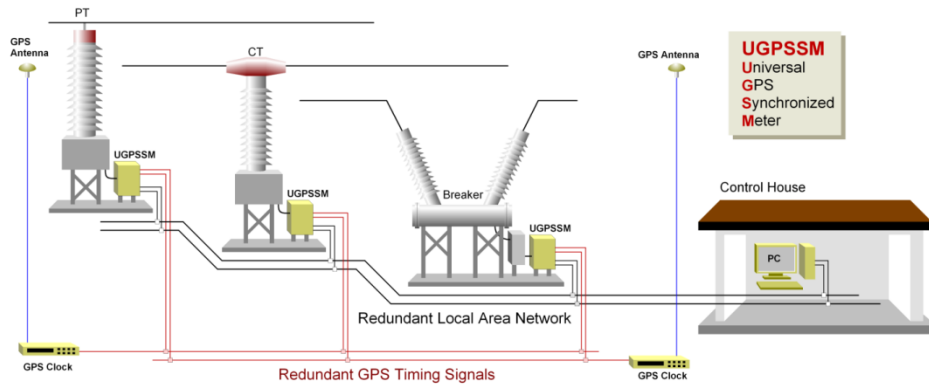
Angle contour results for 13,000 bus Midwest test system. PSERC research is showing how PMU values can be directly combined with existing power flow cases to enhance situational awareness.



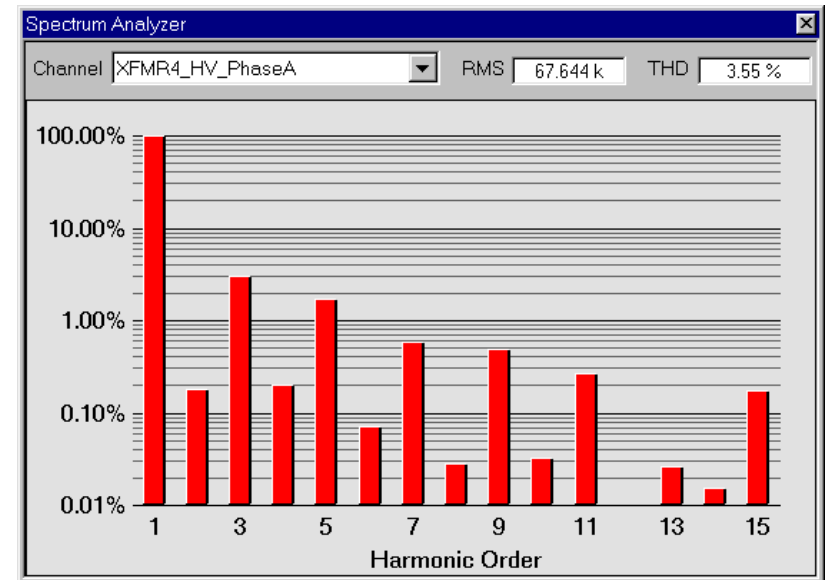
Doubly-fed induction generator. PSERC researchers found that high penetration of wind-powered DFIG's may affect transient stability, frequency response, regulation, voltage response, fault ride-through capability, and load following capability in a power system.

T&D Technologies Research Stem

T&D research improves transmission and distribution systems with technology innovations



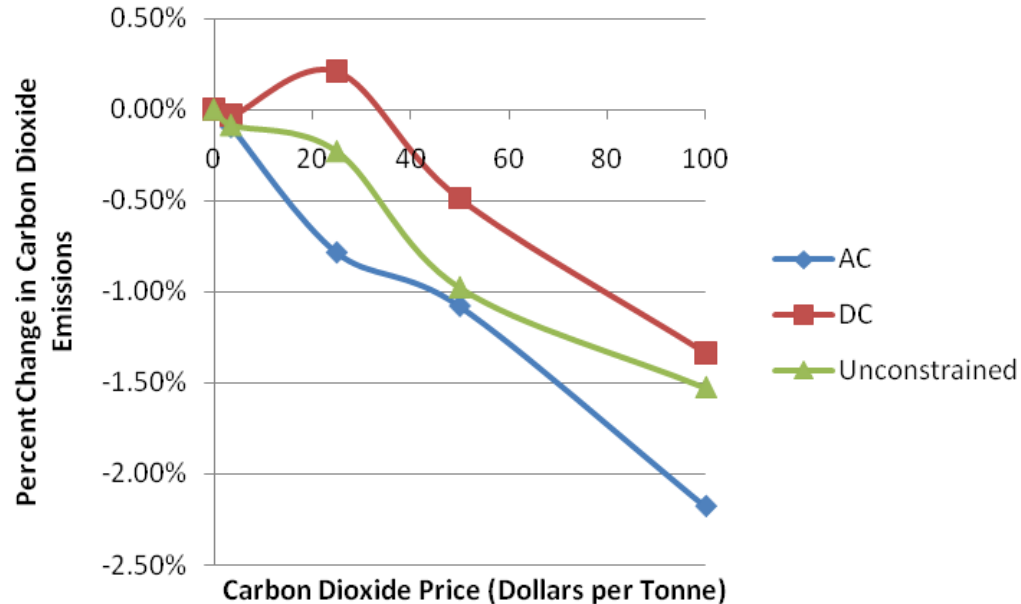
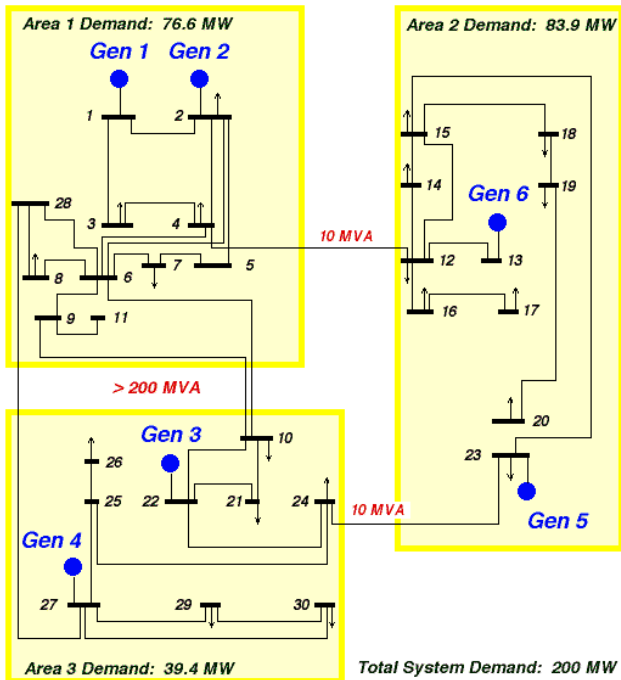
Conceptual view of the substation of the future T&D technology research seeks new ways to achieve efficient and reliable power delivery such as by using new monitoring and control technologies in substations, and new applications in energy management systems.



Tool development is a key part of the research on power quality using physically-based modeling.

Markets Research Stem

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



Economic analyses use test and actual system data to examine on alternative market designs and policies.

PSERC researchers are studying the interaction of carbon emission policies with power system configuration and market design.

Constraint Relaxations: Analyzing the Impacts on System Reliability, Dynamics and Markets

- PI – Kory Hedman, Investigators – James McCalley, Vijay Vittal
- System operators allow various constraints within power flow models to be relaxed, i.e., the constraint can be violated for a set penalty price. Such procedures were undertaken in an effort to: 1) **limit shadow prices** in the markets and 2) reduce the occurrence of **infeasible solutions**.
- This project team will: 1) develop a risk-based model to understand and report the impact of constraint relaxations on reliability, 2) develop stability models that examine the impact of constraint relaxations on system dynamics, 3) conduct economic and reliability studies to determine the appropriate price cap on the shadow prices and compare these findings to the currently implemented caps, 4) analyze the market implications of using price caps on shadow prices as well as propose alternative mechanisms.

Constraint Relaxations: Analyzing the Impacts on System Reliability, Dynamics and Markets

- Chien-Ning Yu (ABB), Feng Gao (ABB), Khosrow Moslehi (ABB)
- Xing Wang (Alstom Grid), David Gray (Alstom Grid)
- Jim Price (California ISO)
- Mahendra Patel (EPRI), Robert Entriken (EPRI)
- Feng Zhao (ISO New England)
- Li Zhang (Midcontinent ISO)
- Erik Ela (NREL), Marissa Hummon (NREL)
- Michael Swider (New York ISO), Muhammad Marwali (New York ISO)
- Alva Svoboda (PG&E)
- Hong Chen (PJM), Jay Liu (PJM)
- Juan Castaneda (SCE)

Problem in the industry

- Constraint relaxation:
 - A constraint can be violated for a set penalty price
 - This practice imposes a limit on the constraint's shadow price (dual variable)
- **Example:**
- A transmission line has a rating of 200MW
- The relaxation price is \$5,000/MWh
- The market model will allow the line flow to exceed 200MW if the shadow price (flowgate marginal price) exceeds \$5,000/MWh
 - The flow will exceed the limit until the shadow price comes down to \$5,000/MWh

Problem Rationale

- Approximations in market models can adversely affect the ability to find good feasible solutions
 - CAISO ignores Power Transfer Distribution Factors (PTDFs) that are between -0.02 to 0.02; flowgate marginal prices may become too high due to this minimum effectiveness threshold;
 - Constraint relaxations essentially counteract these approximation issues by not requiring the market to find an “exact solution” to an imprecise, approximate model
 - Method to cope with model infeasibility

Project Description and Motivation

- Develop models, conduct studies, to address the following concerns:
- Identify the critical constraint relaxation practices
- Determine the impact on reliability and system dynamics
- Develop a framework to determine risk exposure by employing constraint relaxation practices
- Determine the true marginal value limit
- Investigate impact on market prices, market surplus, and market participants
- Investigate alternative market mechanisms

Day-ahead Scheduling

Day-Ahead Market Process

Day-Ahead Market

Relaxed Constraints

- Node Balance
- Spinning Reserve
- Non-spinning Reserve
- Transmission

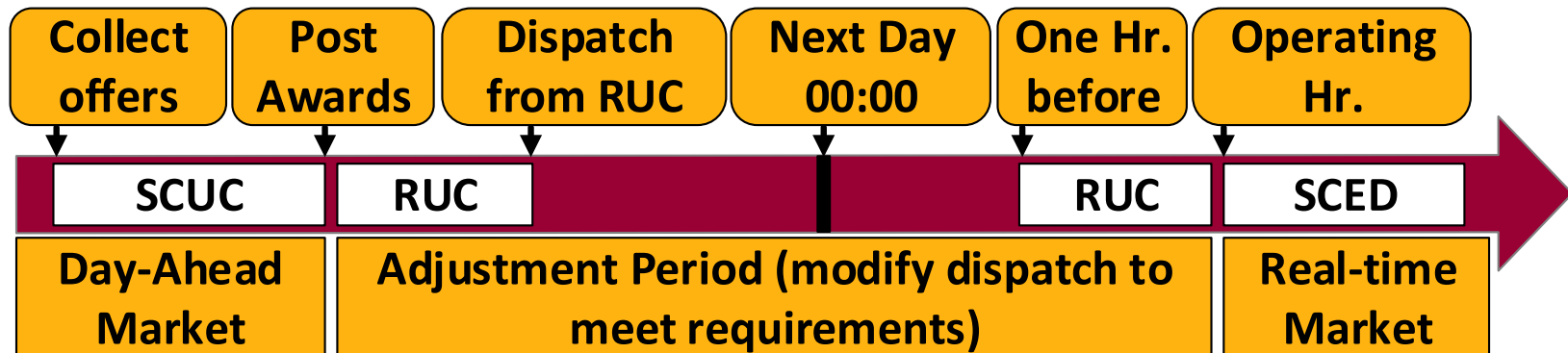
Dispatch Solution
with Relaxations

Out-of-Market Corrections

Industry

- Exceptional Dispatches - CAISO
- Uneconomic Adjustments - CAISO
- Out-of-Sequence - ERCOT
- Out-of-Merit Energy - ERCOT
- Supplemental Dispatches - NYISO

Ongoing
Rescheduling
to Real time

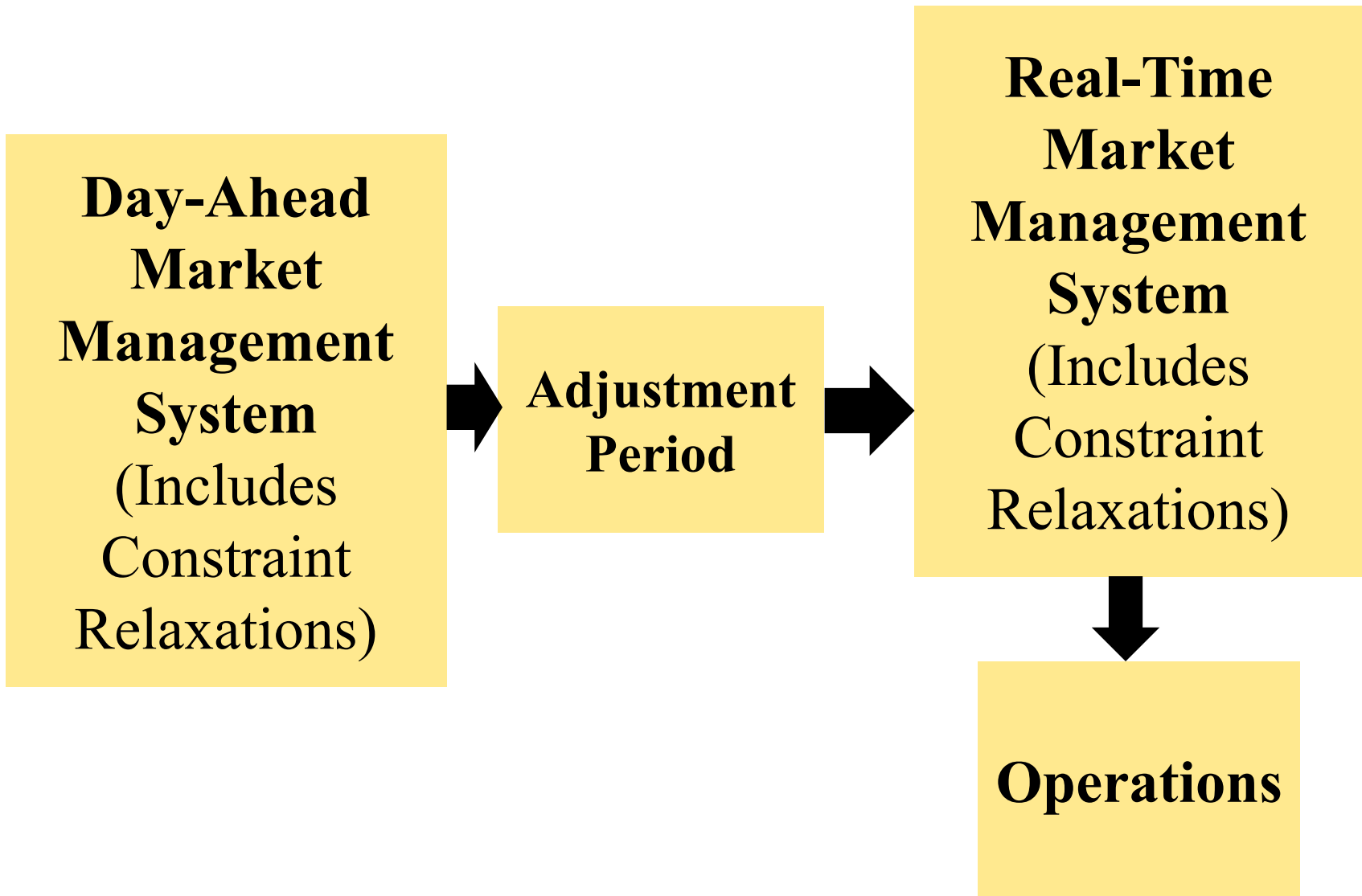


RUC: Residual Unit Commitment

Industry Feedback and Concerns

- **Are all relaxations corrected before actual real-time system operations (do these relaxations show up in actual operations)?**
 - E.g., transmission line limits; reserve requirements
- Feedback: **Most relaxations are corrected** during adjustment periods (the constraints are not violated during real-time operations) before real-time operations
- Feedback: **Yes**, there are times when a relaxation will show up in real-time operations (e.g., a line thermal limit can be violated – IROL, SOL)

Market Adjustment Process



Industry Feedback and Concerns

- **Do you conduct stability analysis (in real-time) to determine if the system is vulnerable due to the relaxations?**
- Feedback: no
- **Future work: need to analyze impact on system stability and associated risk**

Industry Feedback and Concerns

- **Are the relaxations associated to pre-contingency (normal operations) constraints or post-contingency constraints?**
- Feedback: 90% of relaxations are associated with post-contingency constraints
 - E.g., a line flow in the post contingency state exceeds its short-term emergency rating within the optimization engine (note that the contingency event may never happen)

Industry Feedback and Concerns

- **Do you have models that distinguish (and bias) relaxations for pre-contingency constraints versus post-contingency constraints?**
- Feedback: no
- **Should we distinguish pre-contingency relaxations versus post-contingency relaxations?**
- Feedback: not sure; this is something that needs research
 - Insight: Pre-contingency relaxations *will occur* whereas post-contingency relaxations will only occur if the contingency event occurs
 - **Future work: analyze risk associated to pre-contingency versus post-contingency relaxations; suggest new modeling techniques**

Industry Feedback and Concerns

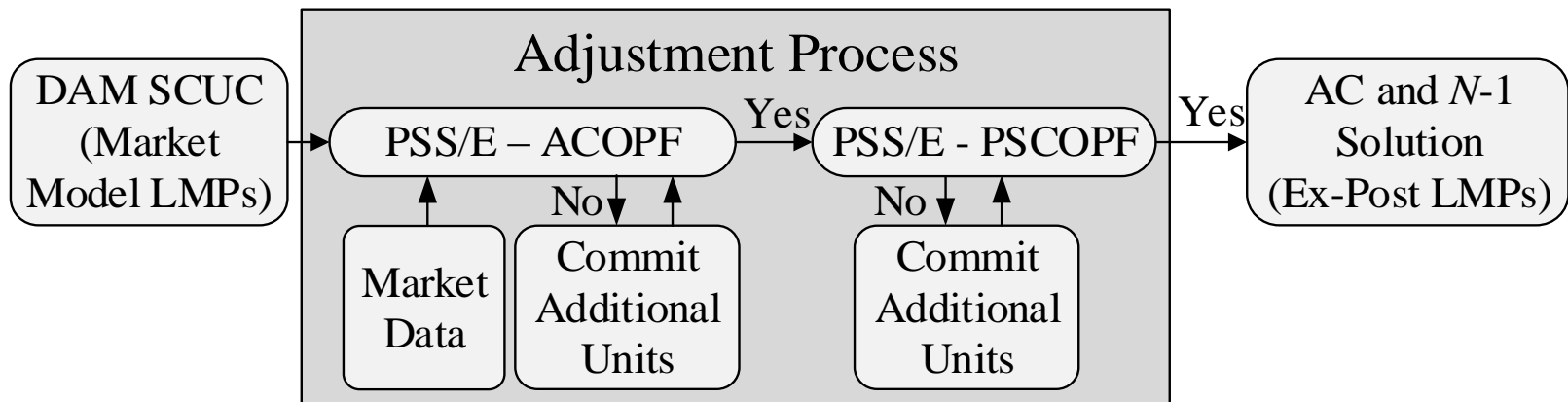
- **Operators will manually choose to bias (de-rate) line ratings in an attempt to ensure that if a relaxation occurs within the real-time market that the actual line flow will not exceed the actual normal line rating (the de-rated capacity may be violated but not the normal rating)**
- **Future work: investigate and propose a way to automate this procedure as opposed to having this manual adjustment**

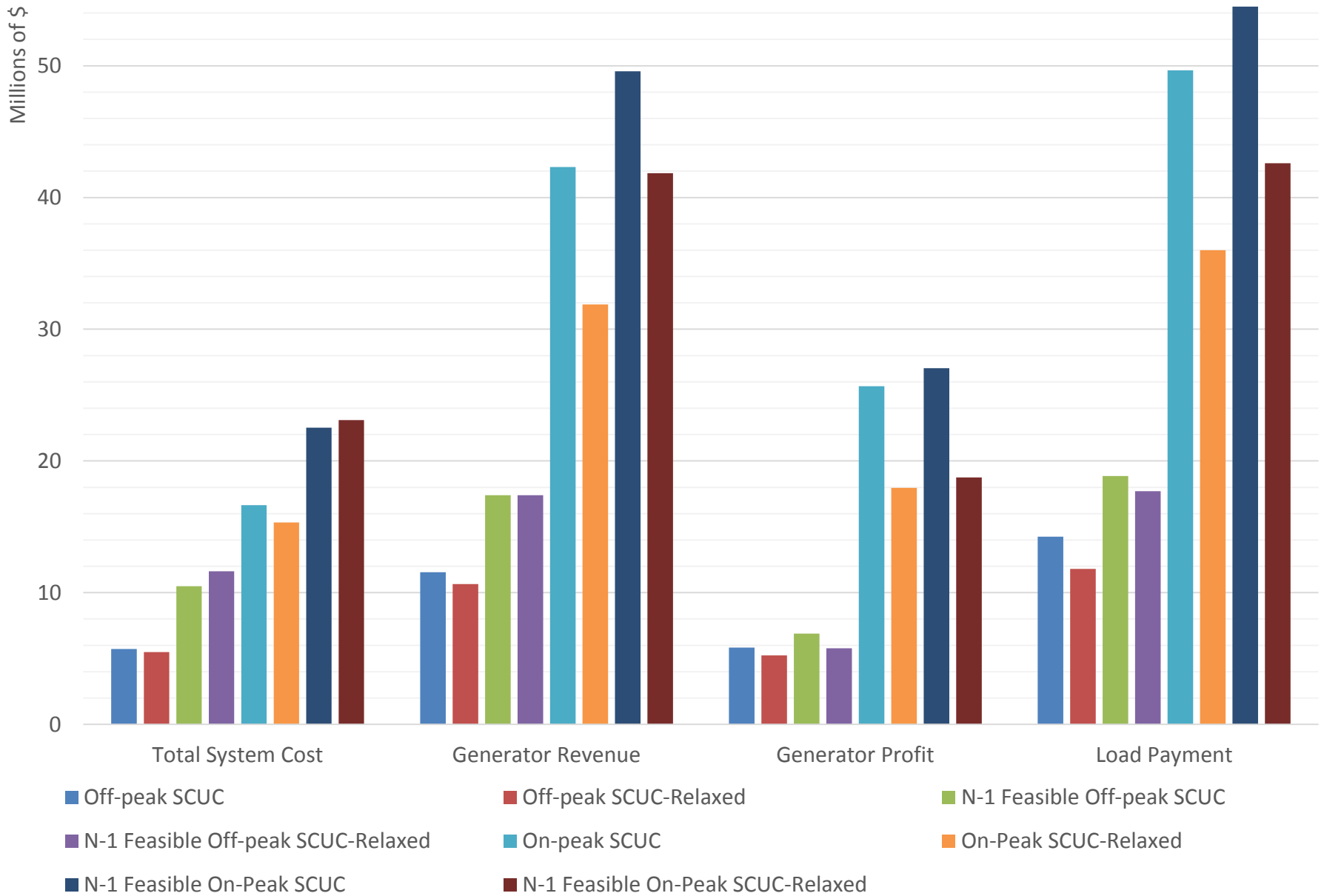
Large test case

- Number of buses ~ 15200
- Number of branches ~ 14400
- Number of generators ~ 2800
- Two winding transformers ~ 6200
- Switched shunts ~ 1200
- Day-ahead market settlement conditions for off-peak and on peak hours

Corrective procedure

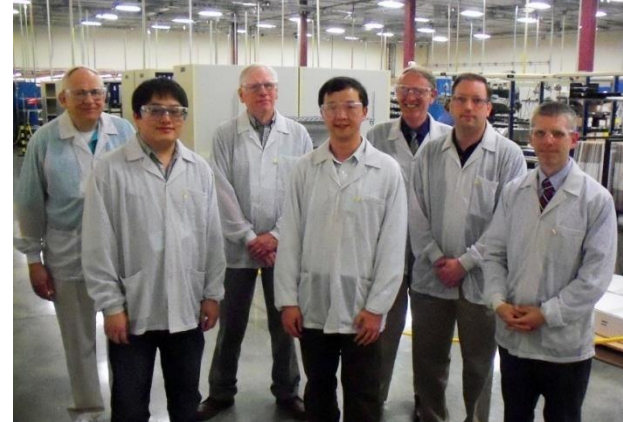
- With PSS-E
 - Adjusted base case schedules to get AC feasible dispatch schedules
 - Used Preventive Security Constraint OPF (PSCOPF) tool to get N-1 secure schedule





Collaboration is Key

- PSERC meets its mission using collaboration within communities of interest
 - Between universities
 - Between industry / university members
- Collaborating working groups include:
 - Stem committees
 - Project teams
- Partnership in:
 - Identifying issues and needs
 - Creating, choosing, and implementing projects
 - Disseminating results



Developments in leading-edge technologies are discussed at semi-annual PSERC meetings. Here meeting attendees are touring a power electronics manufacturing facility.