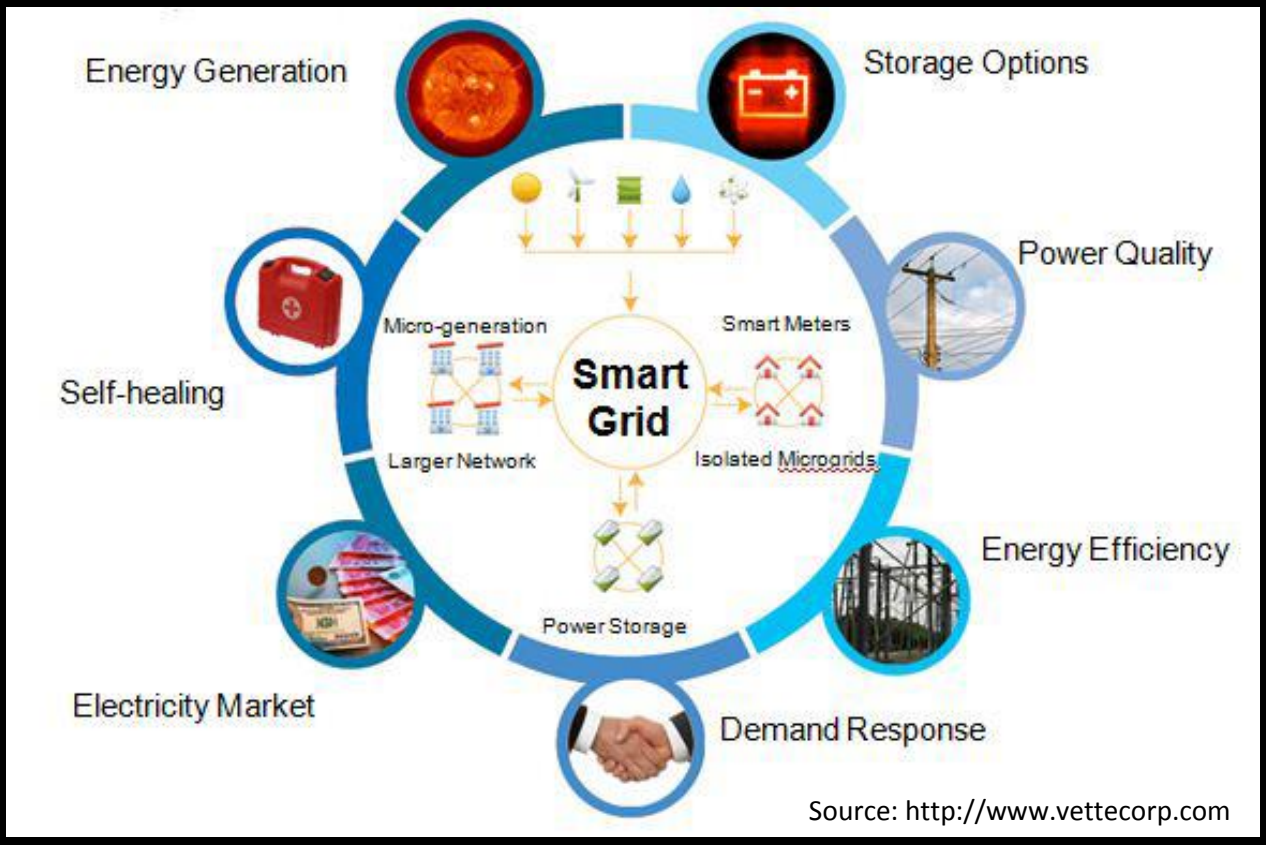
Systems and Optimization Aspects of Smart Grid Challenges 2013

University of Arizona
Tucson, Arizona
March 21 – March 23, 2013



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National Science Foundation:
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Steering Committee:

Feng Pan, Los Alamos National Laboratory
Young-Jun Son, University of Arizona
Neng Fan, University of Arizona
Steffen Rebennack, Colorado School of Mines
Panos M. Pardalos, University of Florida

Workshop Program Overview

Dress code for the meetings and dinners is casual

THURSDAY, MARCH 21ST

(*Kiva Room at Student Union (Level 2), The University of Arizona*)

8:00 am-8:15 am	Registration and continental breakfast
8:15 am-8:30 am	Welcome and opening remarks (**Jeff Goldberg**, Dean)
8:30 am-9:30 am	Plenary Session: **Bert Bras**
9:30 am-10:00 am	Coffee break
10:00 am-12:00 pm	Session 1
12:00 pm-1:00 pm	Lunch (**Rincon room at Student Union (Level 3)**)
1:00 pm-2:30 pm	Session 2
2:30 pm-2:45 pm	Coffee break
2:45 pm-3:45 pm	Plenary Session: **Steven Low**
3:45 pm-4:00 pm	Coffee break
4 00 pm-5:00 pm	Session 3 (**Presidio room at Student Union (Level 4)**)
6:00 pm-8:30 pm	Workshop Dinner (UA Hall of Champions, Speaker: **Roger Angel**)

FRIDAY, MARCH 22ND

(*Santa Ritta Room at Student Union (Level 3), The University of Arizona*)

8:00 am-8:30 am	Registration and continental breakfast
8:30 am-9:30 am	Plenary Session: **Ian A. Hiskens**
9:30 am -10:00 am	Coffee break
10:00 am -12:00 pm	Session 4
12:00 pm-1:00 pm	Lunch (**Rincon room at Student Union (Level 3)**)
1:00 pm-2:30 pm	Session 5
2:30 pm-2:45 pm	Coffee break
2:45 pm-3:45 pm	Plenary Session: **Ross Baldick**
3:45 pm-4:00 pm	Coffee break
4:00 pm-5:00 pm	Session 6
6:00 pm-8:30 pm	Dinner (on your own; Pasco Kitchen & Lounge, 820 E University Blvd, Tucson, AZ 85719)

SATURDAY, MARCH 23RD

(*Kiva Room at Student Union (Level 2), The University of Arizona*)

8:00 am-8:30 am	Continental breakfast
8:30 am-9:30 am	Plenary Session: **Panos M. Pardalos**
9:30 am-9:45 am	Break
9:45 am-10:45 am	Session 7

Plenary Talks
(Abstracts)

Optics for Cheap Solar with CPV Cells

James Roger Prior Angel
Optical Sciences and Astronomy
University of Arizona and REhnu Inc

March 21, Thursday, 7:00pm – 7:30pm (Part of workshop dinner event)

Roger Angel has developed concepts and technology for some of the most powerful astronomical telescopes, including the Large Binocular Telescope and the planned Giant Magellan Telescope. Today he is working on novel ways to harvest solar energy by focusing sunlight with mass-produced, self-supporting glass mirrors onto small but powerful photovoltaic cells. These methods hold the promise of solar electricity at a cost competitive with fossil fuel generation.

Roger Angel is Regents Professor of Astronomy and Optical Sciences at the University of Arizona, where he directs the Steward Observatory Mirror Lab. He is a member of the National Academy of Sciences and the American Academy of Arts and Sciences, a Fellow of the Royal Society and a former MacArthur Fellow and a co-recipient of the 2010 Kavli Prize in Astrophysics. He founded and is CTO of REhnu Corporation.

Systematic Optimization of Transmission Expansion and Transmission Charges based on Benefits

Ross Baldick
Department of Electrical and Computer Engineering
University of Texas at Austin

March 22, Friday, 2:45pm – 3:45pm

There have been many formulations of "optimal" electric transmission expansion in the academic literature; however, with very few exceptions systematic optimization techniques have not been applied to transmission planning in practice. For example, the recent planning of over $5 billion of transmission expansion for Texas to support increased wind involved trial and error addition of candidate lines into a power flow modeling process to develop a plan. I discuss some of the various issues that are involved with transmission planning, and argue that at least some of them are susceptible to systematic techniques. Moreover, I will argue that approaches to charging beneficiaries for construction costs according to benefits received, as mandated by the Federal Energy Regulatory Commission effectively requires an optimization framework in order to evaluate those benefits.

Ross Baldick is Professor and Leland Barclay Fellow in the Department of Electrical and Computer Engineering at The University of Texas at Austin. He received his B.Sc. and B.E. degrees from the University of Sydney, Australia and his M.S. and Ph.D. from the University of California, Berkeley. From 1991-1992 he was a post-doctoral fellow at the Lawrence Berkeley Laboratory. In 1992 and 1993 he was an assistant professor at Worcester Polytechnic Institute. Dr. Baldick has published over fifty refereed journal articles and has research interests in a number of areas in electric power. His current research involves optimization and economic theory applied to electric power system operations, the public policy and technical issues associated with electric transmission under electricity market restructuring, the robustness of the electricity system to terrorist interdiction, electrification of the transportation industry, and the economic implications of integration of renewables. His book, Applied Optimization, is based on a graduate class, "Optimization of Engineering Systems" that he teaches in the electrical and computer engineering department at The University of Texas. He also teaches a three-day shortcourse "Introduction to Electric Power for Legal, Accounting, and Regulatory Professionals" and a one-day short-course "Locational Marginal Pricing" for non-technical professionals in the electricity industry. He is a former editor of IEEE Transactions on Power Systems and former chairman of the System Economics Sub-Committee of the IEEE Power Engineering Society Power Systems Analysis, Computation, and Economics Committee. Dr. Baldick is a Fellow of the IEEE and Director of the NSF I/UCRC on Electric Vehicles: Transportation and Electricity Convergence. With Pecan Street Project support, Dr. Baldick and graduate students are leveraging ERCOT plans for EVSEs at an employee parking lot in Taylor to test and implement charging strategies for plug-in hybrid vehicles.

Sustainability Challenges: The Need for a Holistic View

Bert Bras
Sustainable Design & Manufacturing
The George W. Woodruff School of Mechanical Engineering
Georgia Institute of Technology

March 21, Thursday, 8:30am – 9:30am

In this talk, I will outline some interdependencies that exist between the energy sector and other sectors like manufacturing, transportation, and housing. If the goal is to have a truly sustainable energy infrastructure, then we have to take a holistic systems based approach in order to avoid some unintended consequences. For example, from an environmental perspective, if reduction of greenhouse gas emissions is a goal, then coal is clearly not a good choice for electricity generation and one might argue that nuclear and hydro are preferable. But if we consider the emerging issue of water consumption, then we may need different solutions because electricity generation is a major water consumer and may be responsible for the majority of the water consumption in the life cycle of many consumer products. In automotive manufacturing, the indirect water consumption due to electricity generation is about the same as the direct water consumption. In the manufacturing industry, serious challenges also exist for a "smart" grid because most manufacturers have trouble assessing the energy consumption (and its cost) for individual processes. A similar problem exists when one considers the integration of plug-in hybrid electric vehicles in the home energy system. Whereas personal transportation and housing have been designed and treated independently in the past, electric vehicles now link the two through the shared energy source. As I will show, time-of-use rates have a smaller effect on annual utility and fuel costs than integrating a PV system and an electric vehicle.

Dr. Bert Bras is a Professor at the George W. Woodruff School of Mechanical Engineering at the Georgia Institute of Technology since September 1992. His research focus is on sustainable design and manufacturing, including design for recycling and remanufacture, bio-inspired design, and life-cycle analysis. He has authored and co-authored over a 150 publications. He was named the 1996 Engineer of the Year in Education by the Georgia Society of Professional Engineers and received the 2007 Georgia Tech Outstanding Interdisciplinary Activities Award. In 1999-2000, he was part of a group of experts charged by the National Science Foundation and Department of Energy with evaluating the state-of-the-art in environmentally benign manufacturing. From 2001-2004 he served as Director of Georgia Tech's Institute for Sustainable Development.

Model Predictive Control Strategies for Post-Disturbance Corrective Action

Ian A. Hiskens
Department of Electrical Engineering and Computer Science
University of Michigan

March 22, Friday, 8:30am – 9:30am

Critical transmission outages often cause line overloading and voltage degradation. Without corrective action, eventually overloaded lines may trip and/or voltage collapse may ensue. Importantly, these secondary effects evolve relatively slowly, allowing sufficient time for corrective controls to be enacted. This talk will present receding horizon model predictive control (MPC) strategies that capture the relevant dynamics governing the thermal behavior of overloaded transmission lines and voltage behavior of collapse processes. The controls available to MPC include generation set-points, energy storage and load regulation. MPC determines the optimal use of those resources, subject to a variety of constraints that include rate limits and resource availability. The proposed corrective control strategies will be illustrated using a system of around 100 nodes. Extension to larger, more realistic systems will require distributed MPC. The talk will discuss the suitability of various distributed forms of MPC for corrective control of large-scale systems.

Ian A. Hiskens is the Vennema Professor of Engineering in the Department of Electrical Engineering and Computer Science at the University of Michigan in Ann Arbor. He has held prior appointments in the electricity supply industry (for ten years), and various universities in Australia and the USA. Dr Hiskens's research focuses on power system analysis, in particular modelling, optimization, dynamics and control of large-scale, networked, nonlinear systems. His recent activities have focused on systems issues arising from large-scale integration of new forms of generation, and on the development of non-disruptive load control strategies. Other research interests include nonlinear and hybrid dynamical systems. He is actively involved in various IEEE societies, and is Vice-President for Finance of the IEEE Systems Council. He is an Editor of IEEE Transactions on Power Systems, and has formerly served as an Associate Editor of IEEE Transaction on Control Systems Technology and IEEE Transactions on Circuits and Systems. He is a Fellow of the IEEE, a Fellow of Engineers Australia, and a Chartered Professional Engineer in Australia.

Branch Flow Model: Relaxations, Convexification, Equivalence

Steven Low
Computing and Mathematical Sciences, Electrical Engineering
California Institute of Technology
(Joint work with Masoud Farivar, Subhonmesh Bose, Mani Chandy, Caltech)

March 21, Thursday, 2:45pm – 3:45pm

We propose a branch flow model for the analysis and optimization of mesh as well as radial networks. The model leads to a new approach to solving optimal power flow (OPF) problems that consist of two relaxation steps. The first step eliminates the voltage and current angles and the second step approximates the resulting problem by a conic program that can be solved efficiently. For radial networks, we prove that both relaxation steps are always exact, provided there are no upper bounds on loads. For mesh networks, the conic relaxation is always exact and we characterize when the angle relaxation may fail. We propose a simple method to convexify a mesh network using phase shifters so that both relaxation steps are always exact and OPF for the convexified network can always be solved efficiently for a globally optimal solution. We prove that convexification requires phase shifters only outside a spanning tree of the network graph and their placement depends only on network topology, not on power flows, generation, loads, or operating constraints. Finally, we prove that our branch flow model is equivalent to traditional bus injection model and its associated semi-definite relaxations.

Steven H. Low is a Professor of the Computing & Mathematical Sciences and Electrical Engineering Departments at Caltech, and an adjunct professor of both the Swinburne University, Australia and the Shanghai Jiao Tong University, China. He was a co-recipient of IEEE best paper awards, the R&D 100 Award, an Okawa Foundation Research Grant, and was on the editorial boards of major networking, control, and communications journals. He is an IEEE Fellow, and received his B.S. from Cornell and PhD from Berkeley, both in EE.

Optimization and Modeling in Energy Systems

Panos M. Pardalos
Department of Industrial and Systems Engineering
University of Florida

March 23, Saturday, 8:30am – 9:30am

Energy networks are undeniably considered as one of the most important infrastructures in the word. Energy plays a dominant role in the economy and security of each country. In this talk we are going to consider several difficult problems in energy networks, such as hydro-thermal scheduling modeling, electricity network expansion, liquefied natural gas, and blackout detection in the smart grid.

Panos M. Pardalos serves as Distinguished Professor of Industrial and Systems Engineering at the University of Florida. He is also an affiliated faculty member of the Computer and Information Science Department, the Hellenic Studies Center, and the Biomedical Engineering Program. He is also the Director of the Center for Applied Optimization. Dr. Pardalos is a world leading expert in global and combinatorial optimization. His recent research interests include network design problems, optimization in telecommunications, e-commerce, data mining, biomedical applications, and massive computing.

Detailed Workshop Program

March 21, Thursday

Kiva Room at Student Union (Level 2)

8:00-8:15 Registration and continental breakfast

8:15-8:30 Welcome and opening remarks
Jeff Goldberg, Dean of College of Engineering, University of Arizona

8:30-9:30 Session chair: Young-Jun Son

Plenary Session: Bert Bras, Georgia Institute of Technology
Sustainability Challenges: The Need for a Holistic View

9:30-10:00 Coffee break

10:00-12:00 **Session 1** (Chair: Lawrence Snyder)
Harsha Gangammanavar and Suvrajeet Sen
Stochastic Multi-time Scale Algorithm for Economic Dispatch Problems with Intermittent Energy Sources
Tongdan Jin and Jesus Jimenez
Allocation of Distributed and Variable Energy Resources: Objectives, Models and Applications
Lawrence Snyder and Lizhou Mao
Optimizing Locations for Wave Energy Farms under Uncertainty
Matthew Turner, Yan Du and Yuan Liao
Building a Smart Grid Roadmap for the Commonwealth of Kentucky through Stakeholder Engagement

12:00-1:00 Working lunch (Rincon Room at Student Union (Level 3))

1:00-2:30 **Session 2** (Chair: Lihui Bai)
Moeed Haghnevis, Ronald Askin and Dieter Armbruster
Dynamic Modeling of Behavioral-Based Demand Response
Nicholas Jewell, Lihui Bai, John Naber and Michael McIntyre
Analysis of Electric Vehicle Charge Scheduling and Effects on Electricity Demand Costs
Steffen Rebennack
A Practical Introduction to Optimal Power Flow

2:30-2:45 Coffee break

2:45-3:45 Session Chair: Panos Pardalos

Plenary Session: Steven Low, California Institute of Technology
Branch Flow Model: Relaxations, Convexification, Equivalence

3:45-4:00 Coffee break

4:00-5:00 **Session 3** (Chair: Neng Fan) (Presidio Room at Student Union (Level 4))
Arnold Urken
Social Systems and Smart Grid Optimization
Sadik Kucuksari, Amirreza M. Khaleghi, Maryam Hamidi, Ye Zhang, Ferenc Szidarovszky, Guzin Bayraksan and Young-Jun Son
An Integrated GIS, Optimization and Simulation Framework for Optimal PV Size and Location in Campus Area Environments

6:00-8:30 Workshop Dinner (UA Hall of Champions, Speaker: **Roger Angel**)

March 22, Friday

Santa Rita Room at Student Union (Level 3)

8:00-8:30 Registration and continental breakfast

8:30-9:30 Session Chair: Steffen Rebennack

Plenary Session: Ian A. Hiskens, University of Michigan
Model Predictive Control Strategies for Post-Disturbance Corrective Action

9:30-10:00 Coffee break

10:00-12:00 **Session 4** (Chair: Feng Pan)
Vicki Bier and Sinan Tas
Modeling Cascading Failure to Analyze Investments in Improving Robustness
Pengwei Du
Early-warning Defense System for Small-signal Oscillatory Stability
Bo Zeng, Wei Yuan and Long Zhao
Optimal Power Grid Vulnerability Analysis and Protection through A Defender-Attacker-Defender Model
Feng Pan
Controlling Susceptance in Flexible AC Transmission System - Two-Step Exact Method

12:00-1:00 Working lunch (Rincon Room at Student Union (Level 3))

1:00-2:30 **Session 5** (Chair: Lingling Fan)
Lingling Fan and Zhixin Miao
Mixed Integer Programming Based Energy Storage Sizing for a Community Considering Switchable Loads and Utility Dynamic Price
Thomas Salem and John Fox
A 15 MW Experimental Electric Grid Platform to Address Utility Integration Challenges
Prajwal Khadgi, Lihui Bai, Gerald Evans and Qipeng Zheng
Energy Consumption Scheduling in a Smart Grid Using Utility Theory and Agent-Based Simulation

2:30-2:45 Coffee break

2:45-3:45 Session chair: Feng Pan

Plenary Session: Ross Baldick, University of Texas at Austin,
Systematic Optimization of Transmission Expansion and Transmission Charges based on Benefits

3:45-4:00 Coffee break

4:00-5:00 **Session 6** (Chair: Panos Pardalos)
Sumit Mitra, Ignacio E. Grossmann and Jose M. Pinto
Optimal Multi-scale Demand-side Management for Continuous Power-intensive Processes
Praneeth Aketi V. S. and Suvrajeet Sen
Left-Hand-Side-Convex-Hull Pricing: An Electricity Pricing Strategy with Zero Uplifts

6: 00-8:30 Dinner (on your own; Pasco Kitchen & Lounge, 820 E University Blvd, Tucson, AZ 85719)

March 23, Saturday

Kiva Room at Student Union (Level 2)

8:00-8:30 Continental breakfast

8:30-9:30 Session chair: Neng Fan

Plenary Session: Panos M. Pardalos, University of Florida
Optimization and Modeling in Energy Systems

9: 30-9:45 Break

9: 45-10:45 **Session 7** (Chair: Steffen Rebennack)
Xiao Qin, Susan Lysecky, Lin Lin, Janet Roveda, Jonathan Sprinkle and Young-Jun Son
A Modular Framework to Enable Rapid Evaluation and Exploration of Energy Management Methods in Smart Home Platforms
Neng Fan
An Optimized PMU Placement Schedule for Smart Grid

10:45 Closing Remarks

Abstracts
(In the order of sessions)

Stochastic Multi-time Scale Algorithm for Economic Dispatch Problems with Intermittent Energy Sources

Harsha Gangammanavar
Integrated Systems Engineering, The Ohio State University, Columbus, OH 43210, USA

Suvrajeet Sen
Department of Industrial and Systems Engineering
University of Southern California, Los Angeles, CA 90089, USA

Session 1 (10:00am-12:00pm, March 21, Thursday)

A principal challenge associated with integrating wind and other renewable resources into grid operations is their intermittent nature. Moreover, these sources of energy present sub-hourly fluctuations. One way to mitigate the impact of these fluctuations is to incorporate faster reserves, storage devices etc operating alongside the slower conventional generators in the energy network. To maintain the robustness of the grid, network operations must be planned at different time scales: conventional generators should continue to be planned at hourly intervals due to their operational constraints, whereas renewable generators should be planned and operated at sub-hourly intervals. This is what we consider as a multi-time scale planning problem, under uncertainty.

In this regard we present two alternative multi-time scale stochastic programming formulations of the economic dispatch problem. The first one is a myopic model in which we plan for an hour by incorporating the sub-hourly decisions as a follow-on to the hourly decision. The second approach increases the planning period to two hours which allows the flexibility of modifying conventional generator levels at the beginning of the second hour.

We develop an algorithmic framework in which the overall model is based on three principal components: stochastic programming, dynamic control and simulation. A stochastic program provides conventional generator decisions through Stochastic Decomposition method. For these decisions, dynamic control of renewables are recommended using Approximate Dynamic Programming. A recourse function corresponding to the generator plan and control decisions is evaluated which is used to iteratively update the stochastic program. Stochastic Decomposition operating at hourly and Approximate Dynamic Programming at sub-hourly time scale combine together to provide the optimal planning and operation decisions.

A state-of-the-art forecast system like the NWP also helps in reducing the variability of system operation and hence the overall cost. Owing to the computational difficulties of these systems, only a limited number of forecasts are available. We use vector autoregression to model these ensembles which captures the spatial and temporal correlations. This model is then used to simulate the stochastic time series' required by the sampling based multi-time scale algorithm.

We present computational results on small scale, in-area energy microgrids with the two formulations. We analyze the scalability of the algorithm on a large real size energy network as well.

Keywords: Stochastic Decomposition, Approximate Dynamic Programming, Wind simulation, Multi-time scale optimization

Allocation of Distributed and Variable Energy Resources: Objectives, Models and Applications

Tongdan Jin and Jesus Jimenez
Ingram School of Engineering, Texas State University, San Marcos, TX 78666, USA

Session 1 (10:00am-12:00pm, March 21, Thursday)

Smart grid is envisioned to rejuvenate the aging power infrastructure by incorporating several unique features, such as high reliability, self-healing, full controllability, and total participation. A major challenge in implementing a smart grid system is the seamless integration of distributed energy resources (DER) in existing infrastructure. DER units such as wind turbines (WT) and solar Photovoltaics (PV) mitigate the transmission/distribution congestion issues since these resources are located closer to the end consumers. WT and PV systems are appealing due to their zero carbon emissions. However, the output of WT and PV is quite intermittent due to the stochastic wind and weather conditions. High capital and maintenance costs also impede the proliferation of such renewable technologies. In this presentation, we propose a moment-based method to characterize the stochastic behavior of renewable generation units, and develop a decision-support system to guide the allocation and operation of DER units. We investigate the renewable integration problem in two different areas: 1) allocating DER units in distribution networks; and 2) integrating renewable energy in manufacturing facilities, particularly those that consume significant amounts of electricity, such as semiconductor wafer fabs. In the first area, we formulate a multi-criteria stochastic programming model to address the dispersed generation placement issues. The goal is to determine the generating capacity, placement, and maintenance such that the system cost is minimized, while maximizing equipment reliability. The system is designed to meet the stringent reliability and power quality criteria manifested as loss-of-load probability and voltage drops, respectively. A meta-heuristic algorithm is used to search the Pareto optimality of the non-linear decision-making model. In the second area, our interest is focused on the design of a heterogeneous power system to meet the electricity demand and the carbon emission criterion for a single industrial consumer. We present our numerical examples from case studies obtained from the semiconductor manufacturing industry in order to demonstrate the performance of our model. Simulation-based optimization is used to determine the optimal DER type and capacity when multiple renewable resources are available. Our analysis shows that adopting wind power realizes cost-savings in locations where the average wind speed is above 4.8 m/s. The study also shows that wind turbine is a cost-effective technology even if the wind speed is below 4.8 m/s. If the PV installation cost had reduced by 50%, this technology would be affordable in areas where the overcast days are less than 35% in a year.

Keywords: Distributed generation, renewable energy resources, multi-criteria programming, sustainable manufacturing

Optimizing Locations for Wave Energy Farms under Uncertainty

Lawrence V. Snyder and Lizhou Mao
Industrial and Systems Engineering, Lehigh University, Bethlehem, PA 18015, USA

Session 1 (10:00am-12:00pm, March 21, Thursday)

We present models and algorithms for choosing optimal locations of wave-energy conversion (WEC) devices within a wave farm, i.e., an array of devices for harvesting ocean wave energy and converting it to electricity. The location problem can have a significant impact on the total power output of the farm. When incoming ocean waves (incident waves) strike the WECs, they reflect off of them to create scattered waves; moreover, the WECs' up-and-down motion itself creates a third type of wave, known as a radiated wave. In a wave farm, these three types of waves interfere with each other, and depending on the nature of the interference (constructive or destructive), the wave energy entering N devices, and thus the power output of the farm, may be significantly larger or smaller than the energy that would be seen if the devices were operating in isolation. The ratio of the power from an array of N WECs to the power from N WECs operating independently is known as the q-factor, or interaction factor, and this is, essentially, the objective function of our location problem. The q-factor is a highly nonlinear, noncovex function of the WEC locations (see Figure 1). Many authors have lamented the fact that a wave farm optimized for a particular wave environment tends to perform quite poorly when the environment changes just a little. For example, the best-known 5-device layout (Fitzgerald and Thomas, 2007) performs quite well if the incident waves arrive at an angle of $\beta=0$, but the performance degrades almost immediately as β changes; see the blue curve in Figure 2. In this paper, we introduce heuristics for solving the WEC location problem. Using these heuristics, we show that significantly more robust solutions can be obtained by maximizing either the expected or minimum value of the q-factor; see the red and green curves in Figure 2. To our knowledge, this is the first such demonstration of this important fact, which contradicts the conventional wisdom that the sharp drop-off in q depicted in the blue curve in Figure 2 is inevitable, and that most "good" layouts will perform at $q<1$ if β differs from the angle assumed during the optimization. We also discuss solutions that are robust with respect to the wavenumber k, and we describe qualitative analysis such as how the WEC locations change as the characteristics of the uncertain parameters, or the approach toward uncertainty, changes.

Keywords: Ocean wave energy, wave energy conversion (WEC) devices, WEC location problem, q-factor

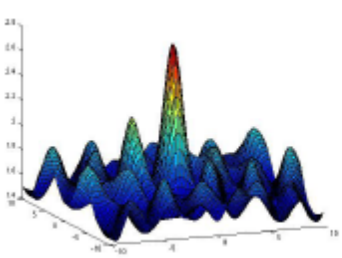

Figure 1. q-factor vs. location of device 1 in a 5-device array.

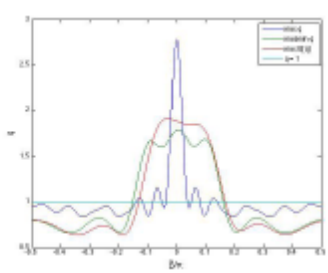

Figure 2. q-factor vs. wave angle β for deterministic, stochastic, and robust solutions.

Building a Smart Grid Roadmap for the Commonwealth of Kentucky through Stakeholder Engagement

Matthew Turner
Electrical and Computer Engineering Technology, Purdue University, New Albany, IN 47150, USA

Yan Du
Electric System Planning, MidAmerican Energy Company, Davenport, IA 52801, USA

Yuan Liao
Electrical and Computer Engineering, University of Kentucky, Lexington, KY 40506, USA

Session 1 (10:00am-12:00pm, March 21, Thursday)

The Kentucky Smart Grid Roadmap Initiative (KSGRI) was a collaborative effort to create a technical roadmap for deploying and developing smart grid technology in Kentucky with the following goals:

1. Enhance energy security though prudent deployment of technology.
2. Improve electric energy efficiency, reliability, and safety of the power system.
3. Facilitate academic, industrial, and governmental partnerships in the areas of technology development and public policy.
4. Provide education on the benefits, risks, and barriers associated with Smart Grid technology deployments.

Recognizing the need for multidisciplinary collaboration and stakeholder buy-in, the KSGRI brought together more than 70 partners from academia, utilities, governmental agencies, non-profits, and energy customers. Engagement was facilitated via self–reporting interrogatories and the Kentucky Smart Grid Workshop Series. Interrogatories distributed to utilities were based on the Carnegie Mellon Smart Grid Maturity Model and collected information in the areas of smart grid deployments and planning, advanced metering, distribution and transmission operations, asset management, distributed energy resources, and customer education programs. A separate interrogatory sent to energy customers, government officials, regulators, and other stakeholders assessed stakeholders' understanding of smart grid concepts and the perceived importance of benefits associated with smart grids. A series of three Kentucky Smart Grid workshops addressed factors likely to inhibit or encourage deployments, the current and future needs of KY's electrical infrastructure, and market and public policy approaches to facilitate smart grid deployments. Through these workshops, stakeholders provided insight into the current status of the Kentucky electric power system, identified opportunities and barriers for grid modernization, and provided opinions resulting in five key recommendations:

1. Encouragement of investments focused on future-proof data network architecture.
2. Creation of an official Kentucky Smart Grid Council composed of academic, industrial, governmental, and stakeholder members.
3. Funding of energy/technology policy and technology development research within the state university system.

4. Creation of regulatory mechanisms to foster increased investments in both cost-effective demand response programs and energy efficiency technologies.
5. Permission for real-time and multi-tariff pricing mechanisms.
6. Establishment of clear metrics to establish priorities and goals for Smart Grid deployments in KY.

Combined, the interrogatories and workshops provided the inputs utilized to form the Kentucky Smart Grid Roadmap, available from the Kentucky Public Service Commission's website at http://psc.ky.gov/Home/Library?type=Cases&folder=2012%20cases/2012-00428. The Roadmap is currently being utilized by the Kentucky PSC as part of Administrative Case 2012-00428 regarding the implementation of "Smart Grid" technologies, including smart meters and time of use pricing.

Keywords: Smart Grid Roadmap, smart meters, regulatory approaches, transmission and distribution, stakeholder Workshops

Dynamic Modeling of Behavioral-Based Demand Response

Moeed Haghnevis and Ronald G. Askin
School of Computing, Informatics, and Decision Systems Engineering
Arizona State University, Tempe, AZ 85287-8809

Dieter Armbruster
School of Mathematical and Statistical Sciences, Arizona State University, Tempe, AZ 85287-1804

Session 2 (1:00pm-2:30pm, March 21, Thursday)

Developing effective price-based demand response (DR) programs is complicated by the lack of supporting technology and behavioral knowledge of the US Electricity Market. An effective DR program requires active retail consumers participating in electricity markets responding to dynamic prices or incentives. Current DR programs are not effective due to several issues: i) most electricity consumers only see flat rates based on total average costs; ii) most current DR programs only consider passive energy efficiency rather than active DR options; iii) programs mainly focus on large industries and businesses; and iv) the reliability of DR programs is reduced due to the lack of social education leading to high uncertainties in consumer participation and customer responses. Previous research focused on consumers' behavior based on rational choice of economical drivers. However, it has been shown that consumers fail to adopt existing incentives because of their low elasticity to the offered drivers. Our research develops a multi-layered socio-technical platform composed of human behavior/social interactions, structural infrastructure and operating rule aspects to describe dynamic demand response in electricity consumption modeled as a complex adaptive system. We assume individual consumers that have preferred consumption patterns but are responsive to social education, peer influences and dynamic prices. To study emergent and evolutionary behavior for the social dynamics of behavioral-based DR, we integrate agent-based modeling (ABM) and optimization techniques, based on recommendations by the U.S. Department of Energy and the Federal Energy Regulatory Commission. Here, individual agents re-adjust their decisions dynamically to optimize their objective values within a range of bounded rationality. These readjustments are generated by local optimization at the micro level leading over time to the emergence of macroscopic patterns at the system level. Specifically we reduce the maximum total electricity consumption variability by motivating consumers to adjust their behavior to limit peak usage with economic incentives and social education. Traditional stochastic learning methods are based on utility optimization models that are built by rational decision theory with limited memory of past experiences. Our framework enables us to combine backward and forward-looking factors along with personal preferences and limited rationality. This combination enables us to mimic actions of real-world behavioral-based DR participants in the US Electricity Markets and forecast individual patterns taking into account more realistic and concrete cognitive capabilities. We examine the behavior of the integrated optimization-ABM system in different environments and show necessary conditions and incentives to achieve load leveling.

Keywords: Agent-Based Modeling and Simulation, Electricity Markets, Behavioral-Based Demand Response, Pattern Forecasting

Analysis of Electric Vehicle Charge Scheduling and Effects on Electricity Demand Costs

Nicholas Jewell*, Lihui Bai†, John F. Naber*, and Michael L. McIntyre*
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Session 2 (1:00pm-2:30pm, March 21, Thursday)

With the recent inflow of Electric Vehicles (EVs) to the automobile market, many have expressed concerns on the resultant additional electrical loads and their negative impacts on an overloaded electric grid. Commercial and Industrial (C&I) electric ratepayers (e.g., businesses, shopping centers, and universities) generally pay for electricity consumption based not only on total energy consumed, but also on peak electric demand measurements. This leads to the so called "demand charge" in C&I ratepayers' electricity bill which typically accounts for over 50% of the total charge. Meanwhile, C&I ratepayers' locations are often considered top choices for installing EV charging stations. Thus, EV owners who desire to charge their EV away from home are likely to use C&I ratepayers' charging facility to fulfill their day-time charging demand. Because certain portions of the working day at C&I ratepayers' facility are traditionally associated with commercial and industrial peak load periods, public charging for EVs would result in significant peak demand increases and hence higher "demand charge" costs for the C&I ratepayer. In this paper, we investigate the means of scheduling EV charging activities for C&I ratepayers to minimize the demand charge. In order to curb the peak demand due to EV charging that coincides with C&I peak load periods, previous research has proposed peak demand predicative control (PDPC) models to predict loads for C&I ratepayers on daily cycles, and to determine the number of charging stations to disable in order to minimize demand charge. The latter may cause the number of working charging stations to be fewer than the number of EVs to be charged. Under this scenario, we model the EV charging scheduling (EVCS) as an off-line parallel machine scheduling problem with machine availability constraints. We consider two EVCS problems. One assumes due dates of all charging jobs are equal (end of day), thus the objective is to minimize the total makespan. The other assumes varying due dates for jobs, thus the objective is to minimize the total tardiness. In both EVCS problems, not all machines are available for a given period. We propose several simple heuristics using the first-come first-serve rule, longest processing time rule, and earliest due date rule to solve the EVCS problems. Additionally, we study the simulated annealing meta-heuristics for both problems. Furthermore, we use CPLEX to solve the mixed integer models for the EVCS for benchmarking purpose. Numerical results using randomly generated data are reported.

Keywords: Electric Demand, Electric Vehicle (EV), Charge Scheduling, Simulated Annealing (SA)

A Practical Introduction to Optimal Power Flow

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Session 2 (1:00pm-2:30pm, March 21, Thursday)

Optimal power flow (OPF) has long been an important and active research area within the electric power systems community. To date, thousands of articles and hundreds of textbooks entries regarding OPF have been published. Despite this familiarity—or perhaps due to it—few good introductory materials for OPF are available for those outside the electrical engineering community. As a result, the accessibility of the OPF literature is skewed heavily toward electrical engineers. In this presentation, we provide a practical introduction to OPF for the operations researcher. We cover the historical context of OPF, compare and contrast several OPF formulations, present the most common types of OPF problems, and discuss modern challenges, including ways that OPF can be applied in smart grids.

Keywords: Optimal power flow, global optimization, electric power systems analysis, electrical engineering, nonlinear programming, optimization modeling, smart grid

Social Systems and Smart Grid Optimization

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Session 3 (4:00pm-5:00pm, March 21, Thursday)

Dynamic control mechanisms based on error-resilient data fusion (ERDF) systems can be designed to enable social interactions of agents and/or humans to meet challenges associated with using communications infrastructure to stabilize Smart Grid infrastructures. ERDF systems make it possible to overcome communications breakdowns, delays and/or decision making errors to optimize Smart Grid performance. By exploiting a time advantage derived from an ERDF window of opportunity, for example, agents in centralized or peer-to-peer network configurations can make reliable ERDF collective inferences about shared voltage line instability and take appropriate countervailing action. Similar ERDF controls could be designed for current control, extending ERDF design by incorporating principles that limit the effects of false positives and false negatives in decision making. .In the context of multi-level sustainability assessment framework (SAF) thermodynamic standards, ERDF inferences can be made from the lower-level to the upper-level to engineer the reliability and timeliness of inferences needed to synchronize SAF systems. For instance, social welfare assumptions about Pareto optimality in the upper level of a SAF could be scrutinized and adapted to optimize bi-level performance by using explicit and revealed preference information to make periodic or ad hoc adjustments. Such interactions could be developed to design and implement time-sensitive incentives that enable Smart Grids to avert or minimize harm and maximize Smart Grid resilience in the face of catastrophic system failure. This type of flexibility will enable Smart Grids to evolve beyond peak shaving to interacting with the distribution grid to stabilize normal load variations to support system robustness. In such a role, "power parks" of Smart Grids could promote distributed generation, storage, and distribution of electricity to provide inter-Smart Grid support and make the national grid more resilient and robust by controlling the harm done by predictable natural disasters. A transition to this type of Smart Grid future will require development of communications standards that meet time-constraints associated with network decision tasks as well normal communications format compatibility. "Time" will also be an important criterion for designing Smart Grid demand-response market mechanisms and for converting "big data" problems such as grid parameter updating by sensors into opportunities for delivering network intelligence to humans that enhances their ability to optimize their performance. The challenge of designing co-operative distributed ERDF communication and control systems will provide another opportunity for optimizing Smart Grid operations to strike the right balance between decentralization and centralized, man-machine control.

Keywords: Emergent, Error-Resilient Smart Grid Control, Multi-Level Smart Grid Social Welfare, Integrating Time into Smart Grid Human and Agent Communications Standards

An Integrated GIS, Optimization and Simulation Framework for Optimal PV Size and Location in Campus Area Environments

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Session 3 (4:00pm-5:00pm, March 21, Thursday)

There has been a growing interest in using renewable energy resources especially for grid-connected Photovoltaic (PV) distributed generation (DG) due to the concerns on increasing amount of pollution as well as reduced cost and improved efficiency of PV technologies. Finding the optimal size and locations for PV units and their integrations while maintaining the grid operation have been a major challenge for distribution system planners as well as researchers. A comprehensive analysis and planning tool that considers economical and technical aspects is needed in order to fully benefit from these systems. In this presentation, a comprehensive framework is proposed integrating Geographical Information System (GIS), mathematical optimization, and simulation modules to obtain the annual optimal and reliable placement and size of PV units for next two decades in a campus area environment. First, given a LIDAR (light detection and ranging) data of the studied area, the GIS module is used to find the suitable rooftops and their panel capacity considering the amount of solar radiation, slope, elevation and aspect. The optimization module is then used to maximize the long term net profit of PV installations considering various costs in investment, inverter replacement, operation, and maintenance as well as savings from consuming less conventional energy (i.e. avoided cost). The network steady state characteristic such as voltage profile of the electricity distribution network of studied campus is then investigated in the simulation module through power flow study. In the case of voltage limit violation due to intermittent PV generations or fluctuations in load, two mitigation strategies, reallocation of the PV or installation of a local storage unit, are proposed. The proposed framework has been implemented for a real campus area involving various software (e.g. ArcGIS, GAMS, PowerWorld simulator), and results show that it can effectively be used for long-term installation planning of PV panels considering both the cost as well as power quality.

Keywords: Distributed generation, GIS, optimal location and size, PV, power quality

Modeling Cascading Failure to Analyze Investments in Improving Robustness

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Session 4 (10:00am-12:00pm, March 22, Friday)

Capacity-constrained networks such as electricity systems are prone to cascading failures, so that even small attacks or low levels of damage can cause significant outages. We propose a game-theoretic model of intentional attacks on electricity systems that also simulates the effect of cascading failure. Our model represents the physics of the electricity network by the optimal DC power-dispatch algorithm. Our simulation of cascading failure is based on a modified version of the OPA model proposed by Dobson et al. (2007), in which cascading failure is assumed to occur with some probability when one or more lines are at or near their maximum capacities. Our results suggest that the impact of cascading failure is non-negligible, but is not highly sensitive to the percentage of transmission capacity at which cascading failure occurs, or the failure probability of overloaded transmission lines. This model allows us to evaluate the effects of interventions designed to reduce the likelihood of cascading failure, including increasing the capacities of critical lines, adding new lines, or reducing the failure probability of overloaded lines (e.g., through smart grid).

Keywords: Cascading Failures, Game Theoretic Model, Robustness

Early-warning Defense System for Small-signal Oscillatory Stability

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Session 4 (10:00am-12:00pm, March 22, Friday)

In a power grid, a key element is real time information interpretation, understanding and visualization to help operators to enhance the reliability and security of power systems. This capability is also referred to in a Federal Energy Regulatory Commission (FERC) policy statement as wide-area situational awareness.

As the liberalization has resulted in variation of load flow over a wide range and an increasing amount of renewable resources are being added to power grid. As a result, the small-signal stability occasionally has been lost for the interconnected power systems. This may limit the transfer capability of major transmission corridors and could lead systems to dangerous situations like the 1996 Western Electricity Coordinating Council (WECC) blackout. However, today's security assessment for the power grid still follows a stovepipe process. Such an approach suffers from a few shortcomings. First, each sensor network produces its own domain-specific data, and such data is processed separately to aid grid operators in making decisions. Second, the current practice in the power grid operations community is to run massive offline analyses to derive model-based guidelines for online real-time operations. However, because power system components and configurations change in real time, it is hard for offline model-based analyses to maintain relevance and effectiveness. Third, the online tools do not analyze the system security tendency with respect to the changing conditions.

This paper presents a novel multi-layer data-driven reasoning tool for early detection of oscillatory instability for bulk power systems. This tool examines different data sources to provide early-warning for small-signal stability vulnerability assessment, infers root causes, and anneals data into actionable information. It also captures model-based and expert knowledge of these complex relationships to help operators recognize problems and apply appropriate actions.

Keywords: Reliability, Security, Multi-Layer Data-Driven Model

Optimal Power Grid Vulnerability Analysis and Protection through A Defender-Attacker-Defender Model

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Session 4 (10:00am-12:00pm, March 22, Friday)

Power grid vulnerability is a critical issue in our society, and its protection problem is often formulated as a tri-level defender-attacker-defender sequential game. However, this tri-level problem is computationally challenging. We design and implement a Column-and-Constraint Generation algorithm to derive its optimal solutions. Numerical results on an IEEE system show that: (i) the developed algorithm identifies optimal solutions in a reasonable time, which significantly outperforms the existing exact algorithm; (ii) the attack solution obtained through solving the attacker-defender model does not lead to the optimal protection plan in general; (iii) protection using the optimal solution from the defender-attacker-defender model always improves the grid survivability under contingencies; (iv) load variation is an important factor in consideration and cannot ignored.

Keywords: Power grid vulnerability, Defender-attacker-defender, Sequential game

Controlling Susceptance in Flexible AC Transmission System - Two-Step Exact Method

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Session 4 (10:00am-12:00pm, March 22, Friday)

In flexible AC transmission system (FACTS), system parameters (e.g., susceptance) can be adjusted to improve the performance of a power grid. We use DC-OPF to model a power grid. Controlling FACTS can then be modeled as a nonlinear bilevel program in which the upper-level is for controlling system parameters and the lower-level is the DC-OPF model. Heuristics were used to solve such models. In this talk, we present a two-step method based on relaxation to solve this problem exactly. Computation time of this method is low in our testing cases of large power grids. The simulation results also show that a power grid can operate efficiently when a subset of lines is switched off.

Keywords: FACTS, Nonlinear bilevel program

Mixed Integer Programming Based Energy Storage Sizing for a Community Considering Switchable Loads and Utility Dynamic Price

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Session 5 (1:00pm-2:30pm, March 22, Friday)

In this project, the size of an energy storage system for a community will be determined based on fixed cost of using the battery, rate of the battery power, utility price and incoming power limit, local load profile, and switchable load penetration. A 24-hour operation problem to minimize the total cost in the perspective of the community will be used to determine the size of the battery. While there is no constraint imposed for the energy size and maximum power size of the battery, the fixed cost of using battery and the rate of battery power will be used as penalty function in the objective function. Without those penalty costs, the size of the battery can of course go infinity. The operation of the battery will show how the battery will be operated given the typical local load profile, external utility price for 24 hours, and limited transfer capacity from the utility. From the battery's operation for 24 hours, energy size and maximum power can then be determined. In addition to local load profile and utility aspect, the local switchable load penetration is also considered for the second operation problem. To facilitate such consideration, the cost function now considers the penalty cost of switching off a load. The switchable loads are assumed to have the same size and the number of them determines the penetration of switchable loads in the community. The main contribution of this paper is two-fold: i) Linear mixed integer programming problems addressing 24 hour operation are formulated considering the above mentioned four aspects of considerations including switchable loads. Techniques to replace nonlinear objective functions and nonlinear constraints by linear objective functions and linear constraints are demonstrated in model formulation. Such formulation makes the large-scale problem solving feasible as linear mixed integer programming can be handled by commercial solvers with very fast speed. ii) Sensitivity analysis are conducted to demonstrate the effect on battery size of utility price, transmission constraints, cost of battery operation, penetration of switchable load and the granularity of the switchable unit. This research can answer the following questions for a community: What size of the energy storage device is most cost effective? If the switchable load penetration is 10%, how much size reduction can be achieved for the battery? How much penetration of switchable load can create most benefits? Finally how much cost saving can be achieved by the battery and/or switchable loads?

Keywords: Demand response, Mixed Integer Programming, Energy Storage, Switchable Loads

A 15 MW Experimental Electric Grid Platform to Address Utility Integration Challenges

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Session 5 (1:00pm-2:30pm, March 22, Friday)

To provide a means for addressing the challenges involved with integrating various renewable energy sources into the utility marketplace, Clemson University is installing a 15 MW hardware-in-the-loop electric grid simulator. This unique electrical test platform features a 15 MW multilevel arbitrary waveform power amplifier configured with a reactive divider network to form a controlled 24 kV experimental three-phase electric grid. This system is designed to produce any possible power line fault condition on the experimental grid at the point of common coupling for a device under test, including even a zero-voltage fault condition. Thus establishing, an experimental test and analysis platform for multi-megawatt systems associated with wind, solar, and energy storage technologies. Additionally, this platform readily facilitates the investigation, at a significant power level, of micro grid and smart grid operating dynamics, electric grid cyber security, and future grid interconnection and interoperability technologies and standards evaluation.

The system architecture has been developed in a flexible, configurable manner such that three independent test bays have been created. All three bays will be able to operate simultaneously, two at 3.75 MW and one at 7.5 MW power level. This allows for concurrent testing and evaluation of multiple multi-megawatt class systems within the facility. As needed, the system can be readily recombined to establish the single 15 MW test platform.

The electric grid simulator is housed within Clemson's Wind Turbine Drivetrain Test Facility, located in Charleston SC, and leverages with the tremendous infrastructure and capital investment of that project. Thus, the complete facility houses the electric grid simulator, and two separate mechanical drivetrain test stands, one rated at 7.5 MW and the other at 15 MW of shaft power capability. Each mechanical test stand has been designed to provide both static and dynamic multi-axial shaft loading of the turbine drivetrain equipment through a controllable hydraulic load application unit. This setup provides the necessary capabilities for accelerated lifetime mechanical evaluation and certification assessment of the turbine's compliance to specific grid codes, like the United States' Federal Energy Regulatory Commission Order 661A.

This presentation details the design, development, and implementation efforts for establishing this unique facility, which is presently in construction and on schedule to begin commissioning activities during the fall of 2013.

Keywords: Utility Integration, Electrical Test Platform

Energy Consumption Scheduling in a Smart Grid Using Utility Theory and Agent-Based Simulation

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Session 5 (1:00pm-2:30pm, March 22, Friday)

The inherent supply process of an electricity distribution system coupled with the uncertainty of demand caused by weather conditions, consumer behavior, etc. can result in a highly unbalanced system. The fluctuation in load within short time periods and the difference in peak and off-peak load call for ancillary services with increased generation costs. Thus, increasing the energy efficiency has not only become a business goal for power companies but a social issue as part of the solution to energy independence. In the advent of smart grid with advanced communication capabilities between energy users and providers, demand side management (DSM) techniques present opportunities for reducing peak loads and thus increasing energy efficiency. In principle, DSM has the ability to charge a customer the true price of electricity at the time of use, and one would think that consumers would shift their load to an off-peak period due to reduced costs. Consequently, most incentives considered in the DSM literature are financial, assuming that cost is the only parameter to influence consumers' load-shifting behavior. However, in practice, customers can override any financial incentives if they feel strongly about the inconvenience of load-shifting arrangements. Thus, we believe that convenience of energy usage is important to consumers, as is cost; and propose an energy consumption scheduling model based on consumers' response to both cost and convenience. In particular, we use utility functions that consider both cost and convenience factors in modeling consumer behavior on energy consumption for prototypical home appliances. The "convenience" herein is defined as being able to use an appliance during one's preferred time window. An agent-based simulation model is used to represent the typical residential population, where households are characterized by their size, income level and risk attitude and the utility functions determined by their risk attitude. We study the effects of dynamic cost structures on this type of utility-based load shifting behavior using agent based simulation, and optimize the system by reducing the peak to average ratio (PAR). Our preliminary results suggest that analysis based on pure financial incentives tend to overestimate the benefit of DSM on load leveling. We conclude that the inclusion of convenience in a utility-function based method is necessary for an accurate study of DSM and its impacts on the efficiency of power distribution networks in a smart grid.

Keywords: Demand Side Management, Smart Grid, Agent-Based Simulation, Utility Theory

Optimal Multi-scale Demand-side Management for Continuous Power-Intensive Processes

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Session 6 (4:00pm-5:00pm, March 22, Friday)

With the advent of deregulation in electricity markets and an increasing share of intermittent power generation sources, time-sensitive electricity prices (as part of so-called demand-side management in the smart grid) offer potential incentives for large industrial customers. These incentives have to be analyzed from two perspectives. First, on an operational level, aligning the production planning with the electricity price signal might be advantageous, if the plant has enough flexibility to do so. Second, on a strategic level, investments in retrofits of existing plants, such as installing additional equipment, upgrading existing equipment, or increasing product storage capacity, facilitate cost savings on the operational level by increasing operational flexibility.

In this work, we propose an MILP formulation that integrates the operational and strategic decision-making for continuous power-intensive processes under time-sensitive electricity prices. We demonstrate the trade-off between capital and operating expenditures with an industrial case study for an air separation plant. Furthermore, we compare the insights obtained from a model that assumes deterministic demand with those obtained from a stochastic demand model. The value of the stochastic solution (VSS) is discussed, which can be significant in cases with an unclear setup, such as medium baseline product demand and growth rate, large variance or skewed demand distributions. While the resulting optimization models are very large, they can be solved within up to three days of computational time. Furthermore, we describe a hybrid bi-level decomposition algorithm, which exploits the decomposable structure of the problem, and is parallelized within the GAMS environment. As a result, the problem instances can be solved within a few hours.

Keywords: Demand-side Management, Power-intensive Processes, Stochastic Programming, Hybrid Bi-level Decomposition

Left-Hand-Side-Convex-Hull Pricing: An Electricity Pricing Strategy with Zero Uplifts

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Session 6 (4:00pm-5:00pm, March 22, Friday)

Electricity pricing is complicated by a variety of factors: inelastic demand, non-convex production sets, market structure and others. Because models of electricity production (e.g. unit commitment models) are mixed-integer programs, the absence of standard convex duality presents a major hurdle for pricing. Currently, there are at least two approaches that have been proposed by certain ISOs in the U.S. One of these approaches promotes economic efficiency and market equilibrium at the cost of high uplift payments which can be used to avoid losses on the part of producers. The other approach is motivated by the need to reduce uplift payments. Our proposal takes the latter proposal even further, by reducing uplift payments to its minimum: namely zero. Our approach, which we term as the left-hand side (LHS) convex hull price, is closely tied to a non-convex value function, and is also closely tied to novel non-convex dual formulation. We show that this pricing approach ensures that producers do not incur losses. The LHS convex hull pricing approach can be interpreted as a variant of both marginal as well as average cost pricing. In this presentation we will provide motivation from an economics perspective as well as the optimization perspective. The method will be illustrated on small examples from the literature. We will also comment on the computational requirements for such a method.

Keywords: Electricity Market Pricing, Left-Hand-Side Convex Hull, Uplifts, Piecewise Linear Dual

A Modular Framework to Enable Rapid Evaluation and Exploration of Energy Management Methods in Smart Home Platforms

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Session 7 (9:45am-10:45am, March 23, Saturday)

Numerous efforts are focused on developing smart grid and smart home platforms to provide monitoring, management, and optimization solutions to more effectively manage energy resources. However, these platforms are extremely complex and require integration of a multitude of parameters such as the end-user behaviors, underlying hardware components, environment, among others. A general and modular framework is developed to enable designers to focus on modeling, simulating, analyzing, or optimizing specific sub-components without requiring a detailed implementation across all levels. A Transaction-Level Modeling (TLM)approach was utilized to build the proposed framework, by which several key components of the framework were modeled including(1) Energy Usage Model, the user's energy usage profile;(2) Energy Generation Model, including renewable resources such as solar panel and wind generation, and their parameters as well as the grid and its pricing policy;(3) Energy Storage Model, such as batteries; and (4) Energy Management Model, the proposed optimization engine that manages the source and load to minimize the energy and/or monetary cost. This framework enables users to consider a holistic view of the platform as well as to evaluate the impact of various energy optimizations. Two case studies utilizing the proposed framework are incorporated: (1)Given a fixed energy usage model, the framework is utilized to quickly evaluate various platform configurations, including multiple energy source options such as solar panels, battery, and grid. Moreover, for each energy source, a variety of configurable options such as the solar panel efficiency, battery capacity, discharge rate, and grid pricing policy are explored to determine the impact on the monthly energy cost. (2)Integration of an energy optimization module to investigate the impact of rescheduling of appliance usage times. Several scheduling algorithms are devised to optimize the appliances' energy usage based on the user energy source configuration and energy usage profile. Slight changes in appliance usage times can have a large impact in terms of monetary cost, yielding an average savings of 33% compared to the original usage schedule. These case studies demonstrate the flexibility and effectiveness of the proposed framework. Developers can easily develop, integrate, and refine subsystems within the platform. These models can reflect new management and optimization algorithms, or models of physical elements such as solar panels or battery banks. As specific elements are updated, developers can easily see how these changes impact the platform as a whole.

Keywords: Smart Grid, Transaction Level Modeling, Simulation, Energy Optimization

An Optimized PMU Placement Schedule for Smart Grid

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Session 7 (9:45am-10:45am, March 23, Saturday)

Recently, phasor measurement units (PMUs) are becoming widely used to measure the electrical waves on a power grid to determine the health of the system. Because of high expense of PMUs, it is important to place minimized number of PMUs on power grids without losing the function of maintaining system observability. This is the optimal PMU placement problem. On the other hand, PMUs should be placed in a multi-phase framework because of budget constraints, and this is the proposed multi-phase PMU placement problem. During each phase, PMUs should be placed to maximize the observability. Therefore, PMUs are placed in a long term schedule to maximize the observability in each phase, while to minimize the total placements. In this talk, we formulate these problems as mixed integer programs with consideration of the zero-injection-bus property in power systems. Additionally, algorithms are designed for solving large power systems and tested on several IEEE systems.

Keywords: Sensor Placement, Multi-phase Placement, Integer Programming

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The above list is confirmed participants as of March 18, 2013. An updated list may be handed out during the workshop.

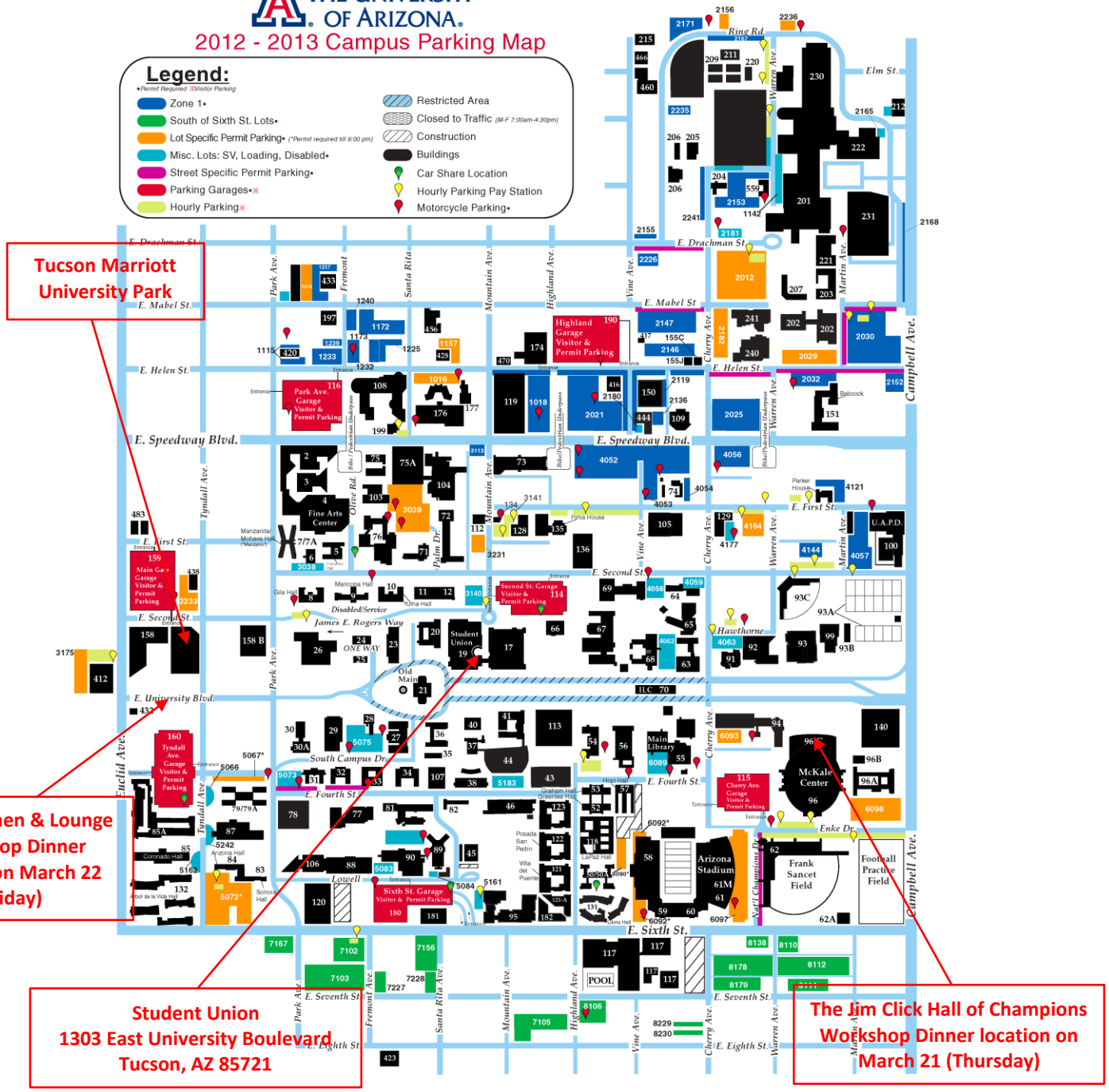
THE UNIVERSITY OF ARIZONA

2012 - 2013 Campus Parking Map

Legend:

•Permit Required ⓗVisitor Parking

- Zone 1•
- South of Sixth St. Lots•
- Lot Specific Permit Parking• (*Permit required till 9:00 pm)
- Misc. Lots: SV, Loading, Disabled•
- Street Specific Permit Parking•
- Parking Garages•ⓗ
- Hourly Parkingⓗ
- Restricted Area
- Closed to Traffic (M-F 7:00am-4:30pm)
- Construction
- Buildings
- Car Share Location
- Hourly Parking Pay Station
- Motorcycle Parking•



Download the Campus Parking Map to your Smartphone

LEVEL 2
(main floor)

ON THIS LEVEL:

FOOD

3 Cheeses & a Noodle
Burger King
Canyon Café & Bistro
Chick-Fil-A
Core
Einstein Bros. Bagels
IQ Fresh
On Deck Deli
Panda Express
Papa John's Pizza
Pinkberry
Sabor
Starbucks
U-Mart

RETAIL

Bookstore
Fastcopy & Design, FedEx
Gallgher Theater
Kaplan Test Prep
US Post Office
Wells Fargo Bank

SERVICES

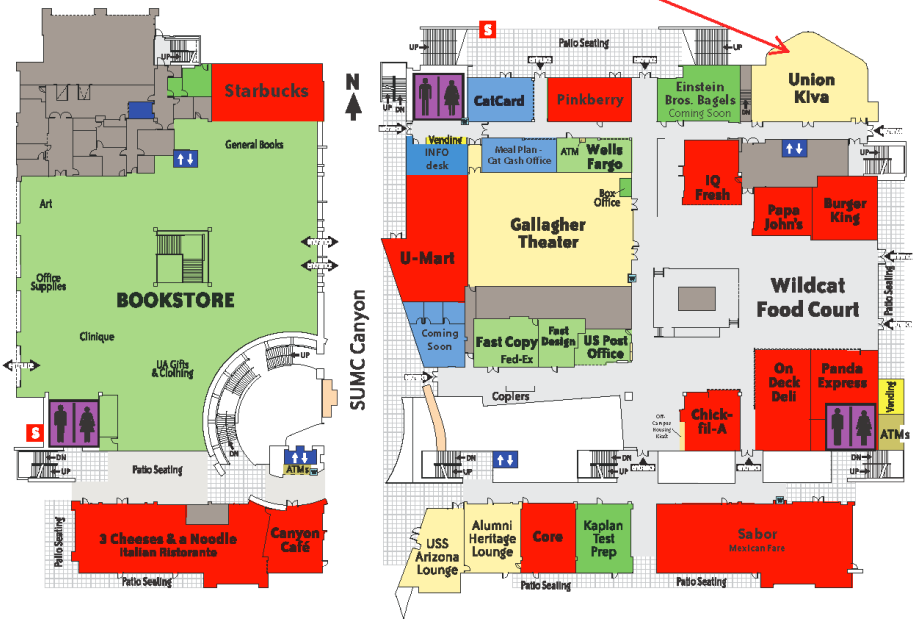
Catcard Office
CatCash Office
Info Desk/Lost & Found
Meal Plan Office

LOUNGES

Alumni Heritage Lounge
Union Kiva Room
U.S.S. Arizona Lounge

Workshop location on March 21 & 23

THE UNIVERSITY OF ARIZONA.



STUDENT UNION MEMORIAL CENTER

FLOOR PLAN & DIRECTORY

Your guide to finding your way in the Student Union Memorial Center.

The Student Union Memorial Center (SUMC) is a place of restricted public access. The SUMC is intended for the use of students, faculty, staff, guests of the University, and participants in authorized on-campus activities. Loitering or interfering with this intended use is prohibited, and violators will be required to leave.

Authority: ABOR Policy 7-201 • UA Campus Use Policy • A.R.S. § 13-2905, -2911

Smoking is permitted only at designated smoking areas.
Smoking is not permitted in all other SUMC areas.

union.arizona.edu **INFO: 621.7755**

LEVEL 1
(lower level)

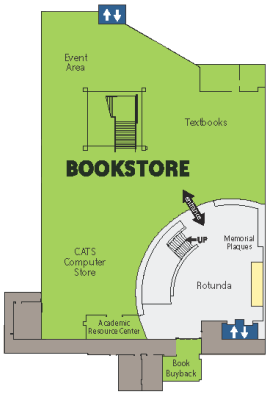
ON THIS LEVEL:

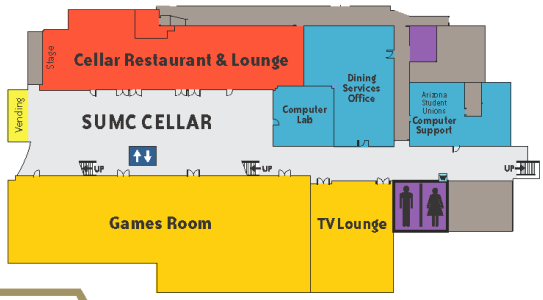
SUMC CELLAR

Cellar Restaurant
Cellar Lounge & Stage
Games Room
TV Lounge
Computer Lab

BOOKSTORE

Textbooks
Computer Store
Event Area
Textbook Buybacks





FLOOR PLAN KEY

Food	Involvement	Services	Water
Retail	Meeting Rooms	Walkway	Restricted
Elevators	Restrooms	Designated Smoking Area	

Rev 09.11

LEVEL 4
(4th floor)

THE UNIVERSITY OF ARIZONA.

ON THIS LEVEL:

INVOLVEMENT

Center for Student Involvement & Leadership
- Blue Chip Program
- Fraternity & Sorority Programs
- Leadership Programs
- LGBTQ Affairs
- Off-Campus Housing
- Pride Alliance
- Women's Resource Center

Transfer Student Center
VETS Student Center

SERVICES

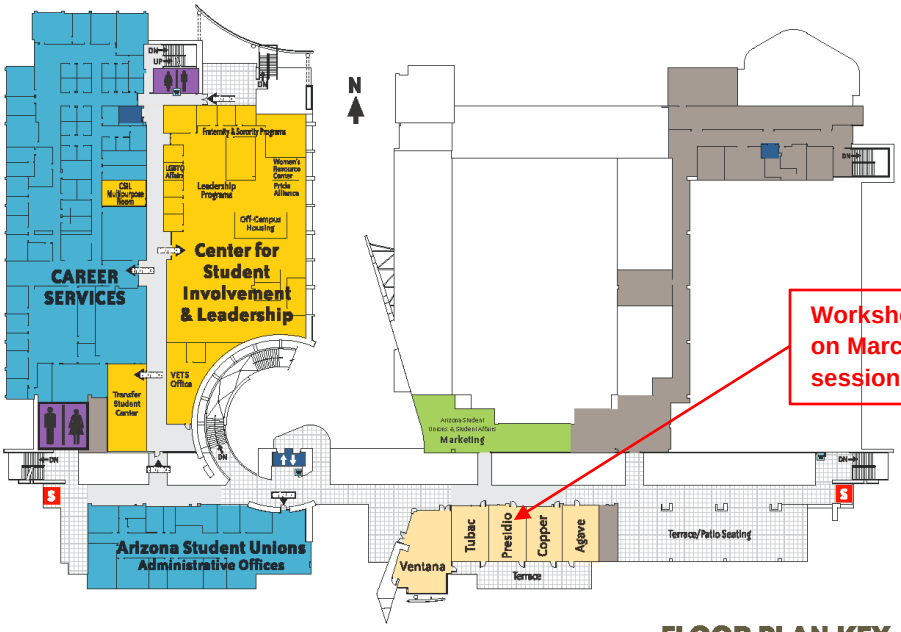
Career Services
Off Campus Housing
Student Unions Admin

MARKETING

Arizona Student Unions & Student Affairs Marketing

MEETING ROOMS

Agave
Copper
Presidio
Tubac
Ventana



LEVEL 3
(3rd floor)

ON THIS LEVEL:

FOOD

Cactus Grill
Fro-yo
Mesa Room
Redington Restaurant

INVOLVEMENT

ASUA
Wildcat Events Board
Graduate Professional Student Council

SERVICES

Event Planning
- Redington Catering
- Room & Mall Scheduling

UA Bookstores Admin
Union Gallery

LOUNGES

Diamond Atrium
Honors Lounge
Kachina Lounge & Gallery

MEETING ROOMS

Grand Ballroom
Catalina
Cholla
Cottonwood
Madera
Mesquite
Ocotillo
Palo Verde
Picacho
Pima
Rincon
Sabino
San Pedro
Santa Cruz
Santa Rita
Tucson

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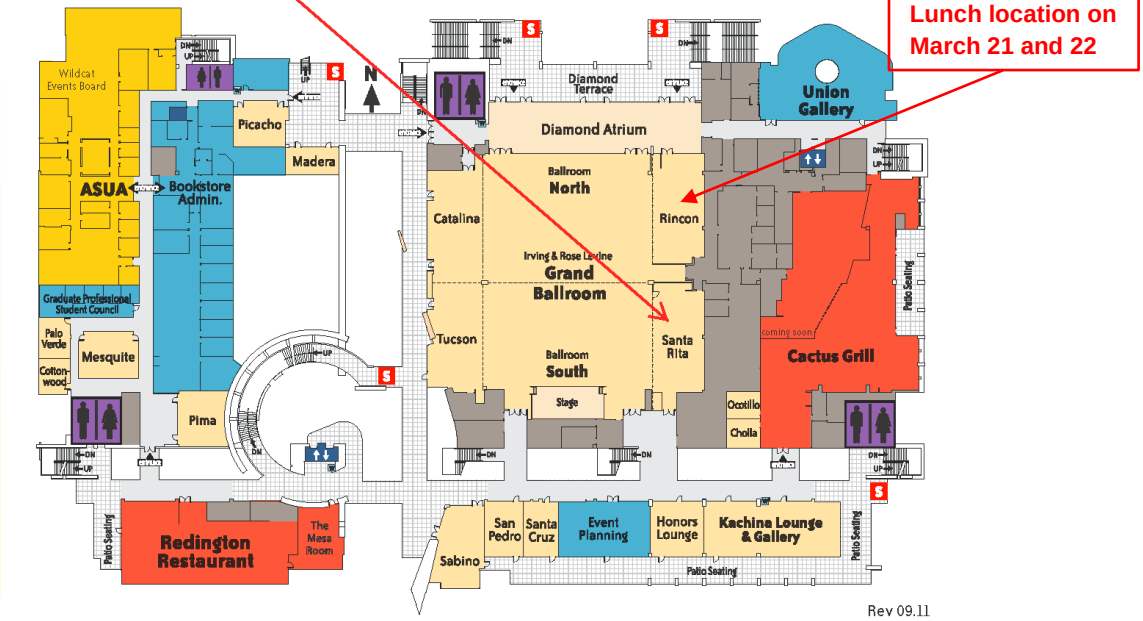

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