AIChE Workshop on Smart Grid for the Chemical Process Industry

September 25-26, 2013 – Illinois Institute of Technology, Chicago, IL
http://www.aiche.org/conferences/workshop-on-smart-grid-chemical-process-industry/2013

Final Program

Overview

Monday September 23, 2013 – Wednesday September 25, 2013

Great Lakes Symposium on Smart Grid and the New Energy Economy
(see http://www.greatlakessymposium.net/ from program details)

Wednesday September 25, 2013

1:30-2:30pm ***Plenary Session*** (Armour Room – Hermann Hall)
2:30-5:30pm ***Invited Session – Demand Response from Buildings Systems*** (Armour Room – Hermann Hall)
6:00-8:00pm ***Workshop Opening Reception*** (Pritzker Club – MTCC)

Thursday September 26, 2013

7:30-11:00am ***Breakfast Buffet*** (Faculty Lounge – Hermann Hall)
8:15-9:15am ***Plenary Session*** (Armour Room – Hermann Hall)
9:30am-12:00pm ***Invited Session – Industrial Demand Response I*** (Armour Room – Hermann Hall)
12:00-1:00pm ***Lunch*** (Alumni Lounge – Hermann Hall)
1:15-2:15pm ***Plenary Session*** (Armour Room – Hermann Hall)
2:15pm-5:30pm ***Invited Sessions – Industrial Demand Response II*** (Armour Room – Hermann Hall)
6:00-9:00pm ***Dinner and Workshop Keynote*** (MT Ballroom – MTCC)

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Wednesday September 25, 2013

Plenary Session (Armour Room, Hermann Hall: 1:30-2:30pm)
Mary Ann Piette, Lawrence Berkeley National Laboratory – Recent Experience and Future Directions of Demand Response Strategies in Commercial Buildings

Invited Session – Demand Response from Buildings Systems
(Armour Room, Hermann Hall – 2:30-5:30pm)
2:30-3:00pm Reduced-Order Modeling Strategies for Predictive Energy Management in Buildings, *Cara Touretzky, Wesley Cole, Atila Novoselac, Michael Baldea, and Thomas Edgar, University of Texas at Austin*
3:00-3:30pm Integrating Large Commercial Building HVAC Operations with Electric Grid Operations and Markets for Significant Efficiency and Expense Savings, *Vincent J. Cushing, QCoefficient, Inc*

Afternoon Break (3:30-4:00pm)

4:00-4:30pm HVAC Control Using Infinite-horizon Economic MPC, *David I. Mendoza-Serrano and Donald J. Chmielewski, Illinois Institute of Technology*
4:30-5:00pm Advances in Multi-objective Optimization and Uncertainty Modeling for Building Systems, *Victor M. Zavala, Argonne National Laboratory*
5:00-5:30pm Energy Microgrids and Integrated Building Solutions, *Rui Huang and Stella M. Oggianu, United Technologies Research Center*

Opening Reception (Pritzker Club, MTCC 6:00-8:00pm)
Reception Address (Pritzker Club, MTCC 6:30-7:00pm)
Maria Burka, Program Director, National Science Foundation – Present and Near Future NSF Funding for Smart Grid Research

Thursday September 26, 2013

Plenary Session (Armour Room – Hermann Hall: 8:15-9:15am)
Ernst Scholtz, ABB Corporate Research – Active participation of Industry in the Smart Grid (with *Iiro Harjunkoski and Xiaoming Feng*)

Invited Session – Industrial Demand Response I
(Armour Room, Hermann Hall: 9:15-12:00pm)
9:15-9:45am Large Industrials and Demand Response in the United States, *David Heitzer, EDF Energy Services*
9:45-10:15am Assessing the Benefits of Stochastic Market Clearing, *Victor M. Zavala, Argonne National Laboratory*

Morning Break (10:15-10:30am)

10:30-11:00am Economic Dispatch of a Combined Heat and Power Plant, *Jong S. Kim and Thomas F. Edgar, University of Texas at Austin*
11:00-11:30am A Distributed Control Framework for Smart Grid Development, *Jinfeng Liu, University of Alberta and Panagiotis D. Christofides, University of California, Los Angeles*
11:30-12:00pm *Speaker Panel*

Lunch (Alumni Lounge, Hermann Hall: 12:00-1:00pm)

Plenary Session (Armour Room, Hermann Hall 1:15-2:15pm)
R. DeWayne Todd, Alcoa Power Generating, Inc., – Process Focused Dynamic Demand Response in Organized Markets

Invited Session – Industrial Demand Response II
(Armour Room, Hermann Hall: 2:15pm-5:30pm)
2:15-2:45pm Flexible and Efficient Operation for Power Generation and Process Industry – A GE Perspective, *Aditya Kumar, GE Global Research*
2:45-3:15pm Use of Low Cost Electrical Power in Petrochemical Process Units, *Dennis O'Brien, Jacobs Consultancy and Donald J. Chmielewski, Illinois Institute of Technology*

Afternoon Break (3:15-3:30pm)

3:30-4:00pm Supply Driven-Operation of Processes, *Alexander Mitsos, Ganzhou Wang and Wolfgang Marquardt, RWTH Aachen University; Amin Ghobeity and Chris Williams, Massachusetts Institute of Technology*
4:00-4:30pm Improving Energy Efficiency with Cogeneration Technology, *David P. O'Brien, ExxonMobil Gas and Power Marketing Company*
4:30-5:00pm Multiscale Optimization for Demand Side Management of Industrial Power-Intensive Processes, *Qi Zhang and Ignacio Grossmann, Carnegie Mellon University*
5:00-5:30pm *Speaker Panel*

Dinner (MT Ballroom, MTCC 6:00-7:00pm)
Workshop Keynote (MT Ballroom, MTCC 7:00-8:00pm)
Joseph Paladino, Senior Advisor, Office of Electricity Delivery and Energy Reliability, US Department of Energy – Experience and Observations from the Smart Grid Programs Funded by the Recovery Act of 2009

Keynote and Plenary Sessions

Wednesday Afternoon Plenary – 1:30-2:30pm, September 25, 2013 – Armour Room, Hermann Hall

Recent Experience and Future Directions of Demand Response Strategies in Commercial Buildings

Mary Ann Piette, Lawrence Berkeley National Laboratory

Abstract: Buildings consume about 40 percent of total energy use in the United States and are responsible for the same percentage of greenhouse gas emissions, and account for about 70 percent of electricity use. Peak demand has also continued to grow causing the need to build a large power grid with more power plants, put large transmission and distribution systems. High peak demand can result in less reliable electricity grids and higher prices. There is an urgent need to develop techniques that reduce energy use and peak electric power in buildings while providing or improving the services provided. This talk will review ten years of research on the development and deployment of technology to automated demand response. The technology is known as OpenADR, open automated demand response. The presentation will also cover results from the field on which strategies are most effective in reducing peak demand in commercial buildings, along with a review of simulation tools to evaluate DR control strategies. The presentation will also include a summary of advanced DR automation projects that evaluate fast time scale control for ancillary services using loads from commercial buildings. DR in buildings is being evaluated to compete with grid scale batteries.

Piette Bio: Mary Ann Piette is the Head of the Building Technology and Urban Systems Department and has been at LBNL since 1983. She is also the Director of the Demand Response Research Center (DRRC). The DRRC develops DR technology and the Open Automated Demand Response standard, which is a key element of the NIST Smart Grid standards. OpenADR is being deployed to deliver over 250 MW of DR in California and throughout the US. Ms. Piette develops and evaluates low-energy and demand response technologies for buildings. She specializes in commissioning, energy information systems, benchmarking, and diagnostics. She has authored over 100 papers on efficiency and demand response. In 2006 Ms Piette received the Benner Award at the National Conference on Building Commissioning for contributions to making commissioning “business as usual”. Ms. Piette completed her undergraduate work at UC Berkeley in Physical Science. She has a Master’s of Science Degree in Mechanical Engineering from UC Berkeley and a Licentiate in Building Services Engineering from the Chalmers University of Technology in Sweden.

Reception Address – 6:30-7:00pm, September 25, 2013 – Pritzker Club, MTCC

Present and Near Future NSF Funding for Smart Grid Research

Maria Burka, National Science Foundation

Burka Bio: Maria Burka is the program director of the process and reaction engineering program in the Division of Chemical, Bioengineering, Environmental and Transport Systems of the National Science Foundation. Past positions include senior scientist with the U.S. Environmental Protection Agency, a faculty member of the chemical engineering department of the University of Maryland−College Park, and a process design engineer with Scientific Design Company in New York City. She has been active in a number of professional organizations, including the American Institute of Chemical Engineers, the American Chemical Society, the Society of Women Engineers, and the American Association of University Women. She served as the 2011 president of AIChE. She received B.S. and M.S. degrees from the Massachusetts Institute of Technology and M.A. and Ph.D. degrees from Princeton University, all in chemical engineering.

Thursday Morning Plenary – 8:15-9:15am, September 26, 2013 – Armour Room, Hermann Hall

Active participation of Industry in the Smart Grid *Ernst Scholtz, Global Program Manager, Grid Automation, Iiro Harjunkoski, Senior Principal Scientist, Xiaoming Feng, Corporate Fellow, ABB Corporate Research*

Abstract: In this presentation we will focus on the main features of the evolving power grid and on how industrial facilities can actively participate by enabling flexible-demand energy consumption in the Smart Grid ecosystem. Increasing information exchange between the power market participants (i.e., producer, consumer, grid operator) is already emerging, and it is conceivable that many industrial sites can plan their consumption and on-site generation (on multiple time-scales) in a dynamic

marketplace. We will highlight the main technical and market components as well as some limitations and challenges (from the grid and energy market side) in realizing the vision of active participation of industrial plants in the Smart Grid.

Scholtz Bio: Ernst Scholtz was born in South Africa where he received his B.Eng. in Electrical Engineering and his M.Eng in Electronic Engineering from the University of Pretoria, in 1997 and 1999 respectively. In 2004, he obtained his Ph.D. degree from the Massachusetts Institute of Technology in Electrical Engineering. He was a Principal Scientist at ABB US Corporate Research, in Raleigh, NC from 2004 to 2008. In this capacity he focused on development of monitoring and control solutions for Electrical Power Transmission Systems and Equipment. In September 2008, he joined EPIC Merchant Energy (now part of EDF Trading) in Houston, TX as a Senior Analyst focusing on analysis of and financial trading in deregulated power markets in the USA. In 2009, Ernst rejoined ABB Corporate Research as the Global Program Manager for Grid Automation where he manages a research portfolio focused on Power Grid Techno-economic Analysis, Automation and Control with projects being executed at Research Centers in USA, Switzerland, Sweden, Poland, India and China. In addition to his Program Manager responsibilities he is also acting as CTO for ABB's Industry Sector Initiative on Smart Grids. Ernst's interests are in the areas of systems, control, and finance theory with a focus on applications in power systems, and industrial processes.

Thursday Afternoon Plenary – 1:15-2:15pm, September 26, 2013 – Armour Room, Hermann Hall

Process Focused Dynamic Demand Response in Organized Markets *R. DeWayne Todd, Alcoa Power Generating, Inc.*

Abstract: Alcoa has successfully integrated dynamic demand response into the electro-chemical processes utilized for smelting aluminum in order to provide highly accurate and reliable Demand Reductions and Ancillary Services in multiple markets throughout the country. This presentation will address how the program was initially structured and tested, the evolution of the engagement, and the types of investments and analysis needed to participate. In addition, the costs and benefits will be examined along with a discussion of achieving balance between corporate and site responsibilities and lessons learned over the past five years.

Todd Bio: DeWayne Todd is the Energy Services Manager at Alcoa's Warrick Operations and serves at the Chief Compliance Officer for Alcoa Power Generating, Inc (APGI). He has worked in the utility industry for over 20 years and has most recently been the project leader for enabling Alcoa's largest US Smelter to participate as an automated demand response provider in MISO's Energy and Ancillary Services Market. In addition to supporting Alcoa's Warrick Operations, DeWayne also provides a Global technical support on Demand Response and compliance to NERC Reliability Standards. DeWayne graduated from the University of Evansville with a B.S. degree in Mechanical Engineering in 1989 and from the University of Illinois with an M.S. degree in Mechanical Engineering in 1992.

Thursday Dinner Keynote – 7:00-8:00pm, September 26, 2013 – MC Ballroom, MTCCl

Experience and Observations from the Smart Grid Programs Funded by the Recovery Act of 2009 *Joseph Paladino, Office of Electricity Delivery and Energy Reliability, US Department of Energy*

Abstract: The U.S. Department of Energy was provided $4.5 billion in 2009 to advance the deployment of smart grid technology in the United States. Two major programs were initiated, the Smart Grid Investment Grant Program and the Smart Grid Demonstration Program, and resulted in a total investment of over $9 billion in 131 projects across the nation. Although the efforts to set up and implement these programs have been arduous, they have catalyzed the movement towards a more modern, digital grid. Joseph Paladino, a senior advisor with the U.S. Depart ment of Energy, will share his experience and observations over past few years that involve the setting up and implementation of these programs.

Paladino Bio: Joe Paladino serves as Senior Advisor within the Department of Energy's Office of Electricity Delivery and Energy Reliability where he oversees the effort to determine the impact of the smart grid projects funded by the American Recovery and Reinvestment Act of 2009. Mr. Paladino has worked at DOE for 20 years in programs involving: a) nuclear waste management, b) energy efficient buildings, and c) electric grid modernization. His particular interest is in the advancement and commercialization of technology. Prior to joining DOE, he worked for over 10 years in the private sector. This experience includes undertaking marketing, sales and technology development efforts at Westinghouse Electric Corporation in Pittsburgh, Pennsylvania. Mr. Paladino has an undergraduate degree in Biology from Middlebury College and a graduate degree in Civil Engineering from the University of Pittsburgh.

Invited Presentations

Demand Response from Building Systems Session (2:30-5:00pm, Wednesday, September 25, 2013 – Armour Room, Hermann Hall)

Reduced-Order Modeling Strategies for Predictive Energy Management in Buildings

Cara Touretzky, Wesley Cole, Atila Novoselac, Michael Baldea, and Thomas Edgar, University of Texas at Austin

Abstract: Model-based controllers for optimal building energy management have attracted significant attention because of their ability to (1) address a primary economic or temperature tracking objective while satisfying system constraints (e.g., occupant comfort levels, HVAC equipment limitations), (2) account for (forecasts of) disturbances (e.g., changes in weather, occupancy, energy prices), and (3) promote demand-shifting that can reduce peak loads. The practical implementation of model-based control is hindered by the size and complexity of the mathematical models of buildings, which are often not amenable to real-time, on-line computations. In this study, we present and discuss a first-principles and a data-driven approach for the identification of low-order building models for use in building MPC.

First, we propose the use of lumped-parameter (or coarse-grained) representations of the building system, which can be derived from grouping structural elements with similar properties into single lumped elements. This framework establishes the (nonlinear) model structure independently from the model parameters, which enhances portability of the model: the same equation structure can be applied to a general class of buildings (e.g., homes in a residential district) and the equation parameters (e.g., volume, density, heat transfer coefficients) can be tailored to a specific building. We also demonstrate how a singular perturbation based time-scale decomposition of the resulting nonlinear coarse grained models can be used to reduce model stiffness and further improve their computational efficiency.

We then discuss a data-driven approach which uses familiar building energy modeling software to create a reduced-order model. A single-zone model is created and imported into OpenStudio, a building energy modeling tool developed by NREL. OpenStudio provides access to multivariate sampling algorithms that can be used in a scripted environment to automatically perturb the building model and collect the results. For example, step or impulse tests can be performed on ambient dry bulb temperature, thermostat set point temperature, occupancy, relative humidity, etc. This allows the user to run hundreds or even thousands of perturbations from a single script and combine the results into one database. System identification methods are then used to identify appropriate reduced-order models (linear or nonlinear) that are computationally efficient in an MPC environment.

Subsequently, we apply both approaches to derive reduced-order models for a residential home. The resulting models are used to synthesize model predictive controllers, which are validated through several simulation case studies, demonstrating their ability to react to disturbances in occupancy and ambient temperature, and to minimize operating costs in the case of variable energy price structures.

Integrating Large Commercial Building HVAC Operations with Electric Grid Operations and Markets for Significant Efficiency and Expense Savings

Vincent J. Cushing, QCoefficient, Inc.

Abstract: QCoefficient (QCo) harnesses the thermal mass of several Chicago commercial office buildings as energy storage to move HVAC energy use from the expensive summer afternoon hours to the inexpensive pre-dawn hours. A case study verifies that QCo's optimization system strategically reduced and shifted several hundred MWhs of HVAC load out of the summer weekday afternoon hours of iconic Chicago building pursuant to five optimization objectives: i) reduce expense (peak demand and energy), ii) reduce energy use, iii) generate demand response revenues, iv) minimize chiller starts, and v) financially manage electric price/volume risk. More importantly, such grid integration enables large energy efficiency retrofit market for buildings and vendors. And such grid integration facilitates financially important grid priorities: price elasticity, renewables, source efficiency and emission reduction, T&D capital deferral, renewables, and night-time price support for baseload generation.

HVAC Control Using Infinite-horizon Economic MPC

David I. Mendoza-Serrano and Donald J. Chmielewski, Illinois Institute of Technology

Abstract: Energy consumption by Heating Ventilation and Air Conditioning (HVAC) systems is usually heaviest when electricity prices are at their highest. The method of Economic Model Predictive Control (EMPC) can be used in conjunction with Thermal Energy Storage (TES) to time-shift power consumption away from periods of high demand to periods of low energy cost. In addition to enormous computational costs, implementation of such algorithms can result in unexpected and

sometimes pathological closed-loop behavior, including inventory creep and bang-bang actuation. This paper will present an infinite-horizon formulation of the EMPC problem. While the design of this controller is achieved by a fairly simple convex optimization problem, it will be shown to alleviate many of the pathological behaviors observed in the finite-horizon case as well as significantly reduce the computational effort required for implementation. The method is illustrated on a simple building example using active TES.

Advances in Multi-objective Optimization and Uncertainty Modeling for Building Systems

Victor M. Zavala, Argonne National Laboratory

Abstract: We present strategies for real-time multi-objective optimization to adaptively trade-off cost, energy, and comfort without the need of tuning weights. We also present Gaussian process modeling strategies to baseline energy use and determine uncertainty levels of energy savings in a rigorous manner following ASHRAE and IPMVP guidelines.

Energy Microgrids and Integrated Building Solutions

Rui Huang and Stella M. Oggianu, United Technologies Research Center

Abstract: Energy microgrids fully integrated with buildings and with the smart-grid isare a promising concept for accelerating the introduction of distributed energy generation. When fully implemented, this concept will provide a large number of benefits ranging from a wider use of renewable resources to improved energy efficiency, power quality and reliability. In order to bring this concept to market, there are a large number of technologies and systems integration concepts that need to be mature alongside with the development of a strong business case for the involved stakeholders. These technologies include microgrid energy and power management systems, alongside with many other enabling technologies such as smart meters, power electronics, communications between stakeholders and microgrid components, implementation of cyber-security, etc. The energy management system (or supervisory system) is responsible for decisions relative to supply and demand energy flows and set-points based on operating costs, customer preferences, utility requests and operational constraints, and communicates these decisions by dispatching set-points to the local controllers. The power management system requires a much higher bandwidth, and needs to provide system stability, coordination between multiple microgrid components, and synchronous connection and disconnection with the grid; alongside with the capability to provide other power services such as power factor and power quality correction. We will introduce some of the power and energy management systems that United Technologies Research Center (UTRC) has been developing and demonstrating, as part of its integrated building solutions portfolio.

Industrial Demand Response I (9:15-12:00pm, Thursday, September 26, 2013 – Armour Room, Hermann Hall)

Large Industrials and Demand Response in the United States

David Heitzer, EDF Energy Services

Abstract: Description of large industrial current participation in Demand Response programs in the United States and the outlook for future industrial participation, market value, and new Demand Response trends throughout the US.

Assessing the Benefits of Stochastic Market Clearing

Victor M. Zavala, Argonne National Laboratory

Abstract: We present a new stochastic programming formulation for day-ahead markets. We show that the formulation provides consistent pricing and enables a more transparent participation of suppliers and consumers with uncertain capacities. We also discuss how stochastic clearing can benefit large consumers with flexible demands and storage capabilities.

Economic Dispatch of a Combined Heat and Power Plant

Jong S. Kim and Thomas F. Edgar, University of Texas at Austin

Abstract: The University of Texas at Austin operates a combined heat and power plant, which provides 100% of its electrical, heating, and cooling loads. The campus is effectively an independent micro-grid and does not rely on the external grid. Although the plant is one of the most reliable combined heat and power systems in the country, it does not currently participate in wholesale electricity markets. If the plant is connected with the external grid and allowed to participate in open electricity markets, it could yield economic and energy savings by selling/buying power depending on market conditions. The objective of this paper is to develop an optimal operating strategy for the combined heat and power plant in the competitive Texas electricity market. The mathematical models of major pieces of equipment present in the plant are developed and validated. These models are applied to the day-ahead energy market to minimize operating costs over a one year period using hourly measured data. The constrained nonlinear optimization problem is solved by the sequential

quadratic programming solver. The simulated results show the optimized operating schedules yield substantial economic and energy savings compared with the historical operating schedules.

A Distributed Control Framework for Smart Grid Development

Jinfeng Liu, University of Alberta and Panagiotis D. Christofides, University of California, Los Angeles

Abstract: In this presentation, we propose a conceptual distributed control framework for electrical grid integrated with distributed renewable energy generation systems in order to enable the development of the so-called "smart electrical grid". First, we introduce the key elements and their interactions in the proposed control architecture and discuss the design of the distributed control systems which are able to coordinate their actions to account for optimization considerations on the system operation. Subsequently, we discuss our results on 1) short-term supervisory control of wind-solar energy generation systems, 2) long-term optimal maintenance and operation of wind-solar generation systems, and 3) distributed supervisory predictive control of distributed wind and solar energy generation systems. In the discussion, detailed simulation models of the wind and solar systems as well as a reverse osmosis water desalination process will be developed. The approach of handling the interactions between these subsystems and the electrical grid will be discussed and extensive simulation results will be shown.

Industrial Demand Response II (2:15-5:30pm, Thursday, September 26, 2013 – Armour Room, Hermann Hall)

Flexible and Efficient Operation for Power Generation and Process Industry – A GE Perspective

Aditya Kumar, GE Global Research and Derick Moolman, GE Intelligent Platforms

Abstract: The demands for flexible and efficient power utilization on the grid are increasing with enhanced focus on renewables and need for energy efficiency across industrial applications. GE is pursuing advances in power generation operation to meet these increasing demands, with emphasis on both conventional natural gas-fired combined cycle power plants as well as renewable sources like wind and solar. This talk will present a high-level description of opportunities and gaps and on-going initiatives to address application of advanced control and optimization for combined-cycle power plants and wind turbine farms. GE also offers commercial control solutions for energy-intensive industries, and one particular focus area of growing importance is on the mining industry. This talk will also highlight some key opportunities and solutions for advanced controls and optimization for efficient and flexible energy use in mining applications.

Use of Low Cost Electrical Power in Petrochemical Process Units

Dennis O'Brien, Jacobs Consultancy and Donald J. Chmielewski, Illinois Institute of Technology

Abstract: One aspect of the smart grid is to use real-time price structures within electricity markets as a vehicle to mitigate source-load inequities resulting from the uncertainty associated with renewable power sources (solar and wind). Under such price structures, those with an ability to change energy consumption rates can expect to capture more profit while providing the societal benefit of improving grid reliability. In most chemical processing facilities, the energy used to drive processes is delivered in the form of steam, which is generated from fossil fuel combustion. In this work, we will illustrate alternative approaches enable by the smart grid context. Specifically, we will then provide a number of examples of how electric power can be introduced within a chemical plant to augment existing utilities. For each case, the operating cost saves will be estimated and contrasted with expected investment costs.

Supply Driven-Operation of Processes

Alexander Mitsos, Ganzhou Wang and Wolfgang Marquardt, RWTH Aachen University; Amin Ghobeity and Chris Williams, Massachusetts Institute of Technology

Abstract: Traditionally processes are run either (i) at nominal conditions to maximize efficiency, or (ii) demand-driven, i.e., the production is varied in time to match the demand. Due to the penetration of renewable energy sources, an additional constraint is imposed on processes, namely that energy supply is time-variable or price of utilities is strongly time-dependent. This results in the need to rethink operation of processes. Examples from commodity chemicals and seawater desalination are discussed. Time-variable supply-driven mode is discussed in today's market and long-term perspectives are given. This is compared to the alternative of energy storage.

Improving Energy Efficiency with Cogeneration Technology

David P. O'Brien, ExxonMobil Gas and Power Marketing Company

Abstract: Cogeneration has been a significant factor in improving energy efficiency at ExxonMobil facilities around the world. With this technology, ExxonMobil can produce electricity to power its operations and capture heat, typically, in the

form of high-pressure steam. In turn, this steam can help transform raw materials into a variety of products. In addition to improving competitiveness through energy efficiency, cogeneration also increases plant reliability and reduces greenhouse gas emissions. ExxonMobil has been in the cogeneration business since the 1950s. As of 2012, we have interests in about 5,200 megawatts of cogeneration capacity established at more than 100 individual installations in more than 30 locations. This is enough capacity to supply the electricity needs of more than 2 million U.S. homes.

Multi-scale Optimization for Demand Side Management of Industrial Power-intensive Processes

Qi Zhang and Ignacio E. Grossmann, Carnegie Mellon University

Abstract: In the chemical process industry, the most significant cost is often the cost of energy. This is especially true for power-intensive processes, such as air separation, chlor-alkali synthesis, and steel manufacturing, in which large amounts of electricity are consumed. In those cases, demand side planning and scheduling can be effective in reducing electricity costs and making such processes more competitive and sustainable. In recent years, the process systems engineering community has started developing optimization scheduling frameworks that involve time-sensitive electricity pricing schemes (Ierapetritou, et al., 2002; Karwan & Keblis, 2007; Castro, et al., 2009; Castro, et al., 2011; Mitra, et al., 2012; Mitra, et al., 2013). These works have resulted in valuable insights on the potential of exploiting the operational flexibility of a process to take advantage of electricity price fluctuations. However, so far, the research efforts have focused on short-term scheduling problems, in which the time horizon considered is typically a week. We attempt to take a step further and develop tools that also help us make demand side decisions on higher levels, such as strategic design investments or integrated production planning and distribution. Here, the main challenge lies in the multiscale character of the problems. In order to take pricing information into account, the level of detail of the model depends on the timescale on which the price changes occur. Therefore, although higher-level decisions with long-term implications are to be made, short-term operational models have to be included in the solution frameworks, which make the problems much more difficult to solve.

In this presentation, we will focus on two works in which we have developed multi-scale demand side optimization frameworks for power-intensive continuous processes. The first one (Mitra, et al., 2013) considers strategic capacity planning over a time horizon of several years. For this problem, we have developed a mixed integer programming model that integrates the optimization of investments and operations under time-varying electricity prices. Moreover, using stochastic programming techniques, the model has been extended such that demand uncertainty can be taken into account. The model has been applied to an industrial case study of an air separation plant. For different scenarios and demand distributions, the current flexibility of the plant and the additional flexibility due to retrofits have been investigated. The second work takes the step from managing merely single plants to the optimization of supply chain networks with multiple production plants. We propose an integrated model that allows the simultaneous multi-scale optimization of production and distribution operations. On the production side, a short-term production schedule is determined whereas on the distribution side, we obtain optimal tactical decisions, such as plant-customer assignments and truck allocation plans. We apply the proposed framework to an industrial gas supply chain and show the benefit of integrated production-distribution optimization with Demand Response considerations.