Poster Session Presentations

This poster session highlights a variety of system approaches to wind energy research including research for grid integration and power system operations, wind resource assessment and turbine performance assessment, wind plant design and balance-of-station costs, stakeholder engagement to address community concerns, the role of sensing in wind plant operations, and even education for the next generation of wind energy professionals.

Poster Title, Author(s) and Organization(s)	Abstract	Biographies
DC Wind Farm Collection System, Michael Johnson, Hao Chen, and Dionysios Aliprantis; Iowa State University	With expected growth of offshore wind farms and the need to transmit inland wind across large distances to population centers, efficient collection and transformation of wind power to high-voltage direct current (HVDC) has been an area of research. Typically, medium-voltage (MV) ac circuits are used to collect the power from the wind turbines with transformers and converters for HVDC transmission. Permanent-magnet synchronous generators (PMSGs) are attractive options for their power density and efficiency. However, PMSGs need fully rated back-to-back ac/dc/ac converters for variable speed operation which cuts into the efficiency of the PMSG. This poster presents a MV dc collection circuit utilizing series connected PMSGs and six-switch two level rectifiers. This topology eliminates the dc/ac converter at each turbine yielding energy savings as well as reducing the components necessary potentially lowering costs. By connecting the turbines in series the bus voltage can be built incrementally over each turbine on a single branch. This removes the need for a step-up transformer, although an isolation transformer is required to allow the generator to be safely grounded. The MV dc bus can be converted to HVDC, HVAC, or low-frequency ac allowing flexibility for transmission of the power. The proposed design also allows for easier incorporation of other dc-based technologies such as photovoltaic and battery storage systems. The system is studied from a steady-state and dynamics perspective using switch level models. An efficiency analysis is performed comparing the new topology to standard collection circuits.	Michael H. Johnson received the B.S. degree in electrical engineering from Iowa State University in 2012. He is currently a Ph.D. student and IGERT fellow in Wind Energy Science, Engineering, and Policy at Iowa State University. His research interests include power electronics, machine drives, and wind energy conversion systems

Preliminary Lake Erie Offshore Wind Farm Monte Carlo Simulation of Maintenance and Repair for Three and Two Bladed Rotors, Brett Andersen and Larry Viterna; University of Toledo	Offshore wind power presents the opportunity for producing energy closer to big cities (load centers). Freshwater bodies of water like the Great Lakes hold huge possibilities for offshore wind development. However, repair and maintenance of offshore wind turbines is much higher than on land. Properly planning resources needed to service offshore wind turbines is essential to estimating costs. This poster will present a preliminary Monte Carlo simulation for unexpected repair costs off the coast of Cleveland in Lake Erie. The paper will take into account the unique challenges that face offshore maintenance: number of boats needed, distance to wind turbines, and number of spare components available. It will also look at the difference of three and two bladed rotors. The Monte Carlo simulation will use randomly generated time between repairs, number of days needed to repair. The simulation will give an idea of the availability of offshore wind turbines, and the costs associated with repair. The monte carlo simulation is part of a larger code being developed by the University of Toledo to estimate the costs and its relation to design of two bladed offshore wind turbines.	Brett Andersen is a PhD candidate at the University of Toledo in Mechanical Engineering. He plans to finish by July. His focus of study is the comparison of two and three bladed rotors in offshore wind energy. He is interested in floating platforms.
Wind Energy Curriculum at Texas Tech University, Padriac Fowler; Texas Tech University	Wind Energy is a rapidly changing industry. This trend is evident across the political, technological, and social spheres. To ensure the viability of wind energy in the United States the industry needs to unify private and public endeavors. To assist in the viability of wind energy, Texas Tech is committed to developing state-of-the-art wind energy educational opportunities. The Texas Wind Energy Institute, in cooperation with the Texas Tech Wind Science and Engineering program, has created a set of educational programs that include a bachelors of science in wind energy, an undergraduate and graduate wind energy certification, a Ph.D. in wind engineering, and a robust professional development program. Our goal is to work with industry to reach those seeking a rewarding career in wind energy, whether they are students just entering the field, or professionals with years of experience looking for advanced training. We offer online programs that issue continuing education credits, and can mentor individuals as well as companies looking to educate their workforce.	Mr. Fowler is a passionate wind energy professional. A meteorologist, engineer, and instructor, he functions across the many disciplines of the wind industry. Previously focused on power prediction R&D, he is presently a faculty member at the National Wind Institute atTexas Tech University, in Lubbock, Texas.

Modeling the Impact of Landowner Participation in Wind Farm Layout Optimization, Le Chen and Erin MacDonald; Iowa State University	Current wind farm layout optimization research assumes a continuous piece of land is readily available and focuses on advancing optimization methods. In reality, projects rely on landowners' participation for success. When a viable site is identified, local residents are approached for permission to build turbines on their land, typically in exchange for monetary compensation. Landowners play a crucial role in the development process, and some land parcels are more important to the success of project than others. Instead of assuming a continuous piece of land is available for the wind farm construction, as in most layout optimizations, our research models landowners' decisions on whether or not to participate in the project as a binary string and incorporates it into the optimization model. A levelized cost model for onshore wind farms, which includes the initial capital cost and annual operating expenses, is used to minimize Cost-of-Energy in the optimization. The initial capital cost includes turbine system costs and the balance-of-station cost. The annual operating expenses take into account the annual operation and maintenance cost, replacement or overhaul cost, and the expenses related to landowner recruitment cost, which is often overlooked by researchers. A Genetic Algorithm (GA) is adopted to solve the nonlinear constrained optimization problem, minimizing cost and maximizing power output. The optimization results show that, given a projected participation rate, we can identify the most crucial plots prior to the negotiation process with landowners. This will ultimately increase the efficiency of wind farm development.	Le Chen is a Ph.D. candidate of Mechanical Engineering at Iowa State University and Affiliated Researcher at the Ames National Laboratory. Her research is focused on optimization of wind farm layout while considering the effect of landowners' preferences.
Wind Farm Layout Optimization Under Uncertainty, Le Chen and Erin MacDonald; Iowa State University	When considering wind turbine placement within an available land area, there are many factors to consider, such as wind resource, availability of land, and topography,.. Each of these factors starts out as a relative unknown at the beginning of the wind farm development process, and through much work becomes a more certain quantity. Unfortunately, many important decisions must be made during early development stages when these factors are uncertain, e.g. developers must determine the initial project feasibility; landowners must decide whether or not to participate in the project. The uncertain	Dr. MacDonald is an Assistant Professor of Mechanical Engineering at Iowa State University and Affiliated Researcher at the Ames Laboratory. Her research integrates concepts from psychology, economics, and marketing into engineering design methods to increase the success of sustainable products and technologies.

	characteristics of the early development stages make these decisions risky. Therefore, our research aims to help both developers and landowners make wise decisions during these early stages. We develop an uncertainty analysis framework for a wind farm layout optimization problem with three uncertain categories: landowner's participation, wind condition, and cost model. A utility-function based Willingness-to-Accept model is developed to represent the uncertain participations of landowners. Wind condition is also modeled as uncertain with an uncertain wind shear exponent parameter—determined through sensitivity analysis to significantly impact final estimated Cost-of-Energy. Lastly, a new cost model with uncertain characteristics is incorporated into the framework. We use Evidence Theory to model the uncertain parameters, and Latin Hypercube Sampling to propagate the uncertainties throughout the system. The entire problem is formed as a robust design problem with two objectives: minimize the normalized mean value and the normalized standard deviation of the Cost of Energy. Finally, compromise programming is adopted to search for the optimal solution that satisfies the two objectives.	
Ramping Reserves with High Wind Penetration, Nicholas Brown, Michael Johnson and Ashley Mui; Iowa State University	The increasing penetration of wind power can lead to forecast net load experiencing errors based on the uncertainty of wind availability in both the upward and downward directions. Greater uncertainty will lead to an increased need for reserves that can be called upon for ramping, which are in addition to the capacity committed for contingencies and regulation. We present an optimization problem with a least-cost dispatch as the objective function, based on an example power system in real-time, including five-minute load, wind power, and conventional fossil generators. The penetration of wind in this system is well above the current level in United States regional power markets, but consistent with aggressive renewable portfolio standards. The combined-cycle gas turbine and combustion turbine ramping rates in the formulation are based on currently available technologies. In this optimization problem we analyzed changes in the dispatch of conventional generating units under varying levels of uncertainty in net load, and based on increased ramping requirements for responding to differences between	Nick Brown is a Fellow in the Wind Energy Science, Engineering and Policy (WESEP) IGERT program at Iowa State University, and is focused on wind integration and operating reserves. He has conducted probabilistic production cost studies for utilities and regulators, and analyzed generators' participation in energy and ancillary services markets. Ashley Mui is a PhD candidate in the Wind Energy Science, Engineering, and Policy (WESEP) program at Iowa State University. She finished her undergraduate in Environmental Science and Mathematics at the University of North Carolina at Chapel Hill. Her dissertation will examine recycling

	actual and forecast net load. When the amount of ramping reserves was increased in order to provide system security, the minimum-cost solution had a reduced dispatch of coal units to provide energy, and additional commitment of natural gas generation to maintain load balance and provide ramping reserves in both directions. The results of additional scenarios are presented, based on market participation by conventional generators and their respective opportunity costs of providing ramping reserves, relative to providing energy.	options and logistics for wind turbine blade disposal.
An Assessment of Offshore Wind Energy Potential Considering Economic Feasibility in Kanto Area of Japan, Yuka Kikuchi; University of Tokyo	The Japanese government introduced the feed-in tariff, in which wind energy is also built in, and the offshore wind energy has come to attract much attention because of the scarcity of sites of onshore wind energy plants. However, there is only a few preceding study on the assessment of economic feasibility of offshore wind energy. Preceding studies did consider only capacity factor, but not cost of energy and internal rate of return, which consists of such elements as annual energy production (AEP), initial capital cost (ICC), and operation and maintenance cost (O&M). Especially as for ICC, an engineering based cost model is required in Japan, because there is few experience data of offshore wind farm constructions. In this study, first, offshore wind climate was investigated by using mesoscale model in Kanto Area of Japan, and verified with meteorological station data. The prediction error of annual mean wind speed was 4.8%. Then, an engineering-based ICC model was proposed as a function of water depth, distance from coast and machine rating. Especially, a support structure cost was modeled by solving vibration equation, which accounted for the considerable portion of the ICC. The ICC estimated by the proposed model showed a good agreement with the existing data in Europe. Finally, the wind energy potential considering economic feasibility was assessed in Kanto Area according to several scenarios for tariffs and subsidies. It was found that tariff which satisfies internal rate of return above 10% was to be more than Y35/kWh.	Yuka Kikuchi is a Ph.D. student of civil engineering at the University of Tokyo since 2012, and a project member of floating offshore wind farm project in Fukushima. Study about the economic optimization for offshore wind energy in Japan. Attend this meeting in order to learn the latest study of techno-economic modeling of wind energy systems.

Wind Energy Cost Production Modeling, Huiyi Zhang and David Jahn; Iowa State University	A wind turbine tower height based cost production (HBCP) model is developed for engineers and developers selecting the most cost efficient wind turbine for a specific wind farm. The model is designed by using Mean Value Theorem for integrals of wind power with respect to wind speed using high temporal resolution data rather than long-term averaging. The accuracy of the wind data ingested into the HBCP is studied through comparison of a modeled regional wind analysis to wind observations at hub height. The HBCP model is then used to explore the economic benefits of increasing hub height, which includes parameters like turbine type, tower height, and installation cost. The model computes changes to increased hub height in 1) installation cost, 2) Annual Energy Production (AEP) 3) payoff period. In addition to optimizing tower height, the model also can be used to detect the maximum allowable generator capacity for the selected site. The accuracy of computing AEP is favorable compared to pertinent commercial models via reducing wind speed uncertainty, eliminating power curve uncertainty, increasing the flexibility of integration intervals. A case study shows that increasing hub height from 80m to 100 m for a GE 1.5MW turbine at Homestead, Iowa, the mean wind speed increases 6.8%, the AEP increases 9.62%, and the payoff period is 4.4 years with a fixed power purchase rate of 6¢/kWh. With observed wind speed data at 150m, the model shows that the maximized generator capacity reaches 6M.	Huiyi Zhang is a Ph.D. Candidate and IGERT fellow at Iowa State University's Wind Energy Science, Engineering, and Policy program. She has five years of work experience at ABB, Exelon, and the Shanghai Institute of Process Automation Instrumentation. Her research interests are turbine blade health monitoring and wind energy cost modeling. David Jahn earned an M.S. in E.E. from the Univ. of Colorado in 1991 and M.S. in meteorology in 1995 from the Univ. of Oklahoma. He has 11 years professional experience as a research administrator and scientist in both a university research center and industry. His focus in meteorological research concentrates on numerical weather prediction on the storm-scale. In 2012 he joined the Wind Energy Science, Engineering, and Policy doctoral program at Iowa State University. His research focus is in the short-term forecasting of ramp events.
Estimating the endogenous power curve – a system-level metric for wind turbine performance analysis, Yu Ding; Texas A&M University	Power curves, the functional relationship connecting wind speed and wind power output, are commonly used in the wind industry for power prediction purpose. It can also be used for characterizing energy production efficiency of a wind turbine generator. Power curves can serve as a system-level performance metric for the entire turbine generator system rather than for individual components therein. Using such system-level metric can thus track the gradual decline, as a result of small wear-and-tear aggregation, in a turbine's power production efficiency, and benchmark a turbine's economic value. Using the raw power production data,	Dr. Yu Ding is Professor of Industrial & Systems Engineering and of Electrical & Computer Engineering at Texas A&M University. Dr. Ding received his Ph.D. degree from the University of Michigan in 2001. He has been developing system-level methodologies for wind turbine's operation, reliability, and maintenance.

	however, cannot accurately reflect the changes in a turbine itself because besides the wind speed, many other ambient factors such as temperature, air pressure, turbulence intensity, wind shear, and humidity all potentially affect the raw power output of a turbine. When people see a change, it is difficult to discern where the change comes from. What is needed is the so-called endogenous power curve, the curve decided by a turbine's own aerodynamics, after the influence from the ambient environmental factors is controlled for. This poster presents the research team's most recent development of a multivariate kernel method for estimating the endogenous power curve as well as its application in turbine performance analysis. Comparisons with the current alternatives are provided in order to demonstrate the merit of the proposed methodology.	
A Case Study on the Effects of Predicted Wind Farm Power Outputs on Unscheduled Flows in Transmission Networks, Manish Mohanpurkar; Colorado State University	The impact of forecasting error in wind power on unscheduled flows (USFs) is investigated here. Normal distribution is used to model the forecasting error distribution. Upper and lower bounds on wind farm output with a positive correlation of errors are obtained. Monte Carlo simulations using the interval forecasts of wind farm outputs are run to obtain interval branch flows. Ordinary least squares and ridge regression are used for the estimation of a mathematical artifact - minor loop flows – for accommodating USFs. Model adequacy and statistical inferences of the loop flow estimates is discussed. Impact of forecasting error on distributions of estimated loop flow is explored on the basis of Kolmogorov-Smirnov (KS) and chi-square goodness-of-fit tests.	Manish Mohanpurkar (S'12) received his Bachelor of Engineering degree in Electrical, Electronics & Power in the year 2008, from Dr. B. A. M. University, Aurangabad, India with distinction. He graduated with a Master of Science (Electrical Engineering) from Oklahoma State University in Dec 2010. He worked as a Research Assistant at the Engineering Energy Laboratory at Oklahoma State, from Aug. 2008 to Dec. 2010. Currently, he is working towards a PhD at Colorado State University, Fort Collins, CO in the area of power system planning for high renewable energy scenarios. Recipient of the prestigious Frontiers of Power/Bill Hughes scholarship in 2009 and won the 3rd prize, poster contest in IEEE PES GM 2012. Presently, his areas of interest are graph theory applications to power systems, planning and operation scenarios of wind energy, and estimation theory.

Offshore Wind Plant Balance-of-Station Cost Drivers and Sensitivities, Genevieve Saur, Ben Maples, Becki Meadows, Maureen Hand, Walt Musial, Chris Elkinton, and J. Clayton; National Renewable Energy Laboratory & GL Garrad Hassan	With Balance of System (BOS) costs contributing up to 70% of the installed capital cost, it is fundamental to understanding the BOS costs for offshore wind projects as well as potential cost trends for larger offshore turbines. NREL developed a BOS model using project cost estimates developed by GL Garrad Hassan. Aspects of BOS covered include engineering and permitting, ports and staging, transportation and installation, vessels, foundations, and electrical. The data introduce new scaling relationships for each BOS component to estimate cost as a function of turbine parameters and size, project parameters and size, and soil type. Based on the new BOS model, an analysis to understand the non-turbine costs associated with offshore turbine sizes ranging from 3 MW to 6 MW and offshore wind plant sizes ranging from 100 MW to 1000 MW has been conducted. This analysis establishes a more robust baseline cost estimate, identifies the largest cost components of offshore wind project BOS, and explores the sensitivity of the levelized cost of energy to permutations in each BOS cost element. This poster shows results from the model that illustrates the potential impact of turbine size and project size on the cost of energy from US offshore wind plants.
Wind Turbine Sensing, Scott Hughes, Shawn Sheng, and Jonathan White; National Renewable Energy Laboratory & Sandia National Laboratories	Wind turbines are complex machines with an array of sensing needs. Sensing requirements for wind systems include operation and control of arrays of turbines, and measurement and control of specific machines based on wind inflow conditions and turbine to turbine interactions. Control and monitoring of critical components including geared and direct drive drivetrains, and blade rotor systems is increasingly important for megawatt and offshore turbines. This poster presents an overview of wind turbine sensing, including challenges, opportunities, and relevant activities at Sandia National Laboratories (SNL) and National Renewable Energy Laboratory (NREL).