

Proposal to Conduct a Tutorial on Fundamentals of Wind Energy
IEEE PES 2009 General Meeting
Calgary, Alberta

Submitted by IEEE Wind Power Coordinating Committee
J. Charles Smith, Member, (jcharlessmith@comcast.net)
November 5, 2008

Sponsorship

This tutorial is sponsored by IEEE Wind Power Coordinating Committee (WPCC). Co-sponsors include PSDP Committee, T&D Committee, PSO Committee, EDPG Committee, PSACE Committee, and the Utility Wind Integration Group (UWIG).

Overview of the Tutorial

This tutorial will provide an introduction to the basic considerations associated with planning and operating a power system with wind power plants. An introduction to the wind industry and its status and outlook will be provided, along with a basic understanding of the wind turbine technology and design considerations. The electrical performance of single machines and design considerations for large wind power plants will be addressed. Wind power plant performance, controls and grid codes will be covered in sufficient detail to motivate the discussion of modeling and simulation. Representation of wind power plants in large-scale power flow, transient stability and short circuit studies will be addressed. The increasingly important role of wind forecasting in power system planning and operations will be included, along with a basic understanding of the reliability aspects of system planning with wind plants. A summary of the state-of-the-art in utility wind integration will be provided, as well as the high wind penetration experience from Europe.

Summary of Topics

The following general topics will be covered in the tutorial. Please refer to the attached agenda for more information.

- 1. Overview of Wind Industry*
- 2. Wind Turbine Technology*
- 3. Wind Power Plants*
- 4. Power Grid Operations and Planning with Wind*
- 5. Wind Plant Models for System Studies*
- 6. Wind Forecasting*
- 7. Capacity Value of Wind Plants*
- 8. Utility Wind Plant Integration Studies*
- 9. European Experience with High Wind Penetration*

Organization of the Tutorial

The topics listed above will be covered in a daylong session. This will provide an opportunity to discuss specific examples and field questions from the audience.

The tutorial chair, in concert with the planning committee, will appoint subject matter experts to present each of the major topics outlined above. A subset of these individuals will also serve as the tutorial planning committee. The planning committee will hold a teleconference in early December to determine the final scope and time allocation of each topic, and also to finalize the list of presenters. The proposed presenters have already been contacted and tentatively agreed to participate. A second teleconference will be held in early January to finalize the agenda.

The Utility Wind Integration Group, WECC Wind Generator Modeling Group (WGMG), National Renewable Energy Laboratory and other entities have developed relevant presentation materials which have been presented in various venues. The planning committee will draw on these existing resources in the preparation of presentation materials for the tutorial. Supporting documentation, including reports, guidelines, magazine articles, and brochures will be included in the tutorial booklet for reference purposes.

Tutorial Abstract

Wind generation continues to advance at a rapid pace in terms of technology and installed capacity. In some areas of Europe and North America, wind power plants have already made a major impact on power system performance. This tutorial will provide an introduction to the basic considerations associated with planning and operating a power system with wind power plants. An introduction to the wind industry and its status and outlook will be provided, along with a basic understanding of the wind turbine technology and design considerations. The electrical performance of single machines and design considerations for large wind power plants will be addressed. Wind power plant performance, controls and grid codes will be covered in sufficient detail to motivate the discussion of modeling and simulation. Representation of wind power plants in large-scale power flow, transient stability and short circuit studies will be addressed. The increasingly important role of wind forecasting in power system planning and operations will be included, along with a basic understanding of the reliability aspects of system planning with wind plants. A summary of the state-of-the-art in utility wind integration will be provided, as well as the high wind penetration experience from Europe.

Tutorial Planning Committee Members

- Charlie Smith, Utility Wind Integration Group (UWIG)
- Richard Piwko, General Electric
- Abraham Ellis, Sandia National Laboratories
- Mark O'Malley, University College Dublin
- Robert Zavadil, EnerNex Corporation
- Dale Osborn, Midwest Independent System Operator

**IEEE PES 2009 General Meeting
Calgary, Alberta**

**Wind 101: Tutorial on Fundamentals of Wind Energy
Conducted by Wind Power Coordinating Committee
Contact: J. Charles Smith, Member (jcharlessmith@comcast.net)**

**DATE: Sunday, July 26, 2009
VENUE: TBD**

DRAFT TUTORIAL AGENDA

**Welcome.....8:00 – 8:15
(Richard Piwko)**

**I. Wind Industry Overview8:15-8:45
(J. Charles Smith)**

- Installed capacity and trends
- Current technology and trends
- Current technical challenges (interconnection and integration)
- Grid codes

**II. Wind Turbine Technology8:45-9:30
(Sandy Butterfield)**

- Description of mechanical and electrical systems
- Performance
- Future trends

Morning Break9:30 – 9:45

**III. Wind Power Plants.....9:45-10:30
(Steve Saylor)**

- Collector systems
- Substation
- Reactive power
- Grounding and protection

**IV. Power Grid Operations and Planning with Wind.....10:30-11:15
(Richard Piwko)**

- High wind penetration issues
- Grid codes
- Wind plant performance features

V. Wind Plant Models for System Studies.....11:15-12:00
(Abraham Ellis)

- Wind power plant topology and components
- Single-machine equivalent representation
- Wind plant representation
- Manufacturer-specific models
- WECC generic models
- Guidelines for stability and short circuit studies
- Current industry activities (WECC, IEEE, CIGRE)

Lunch Break..... 12:00 – 1:00

VI. Wind Forecasting.....1:00-2:00
(Pascal Storck)

- Mesoscale modeling, backcasting, and forecasting
- Forecast products and metrics
- Forecast examples
- Integration with grid operations

VII. Capacity Value of Wind Plants.....2:00-2:45
(Michael Milligan)

- Reliability based methods
- Representation of wind in models
- Simple approximations and examples

Break.....2:45-3:00

VIII. Utility Wind Plant Integration Studies.....3:00-4:00
(Robert Zavadil)

- Wind plant behavior
- Variability and uncertainty
- Sources of system flexibility
- Balancing the system
- System economic evaluations

IX. European Experience with High Wind Penetration.....4:00-4:45
(Mark O'Malley)

- Denmark
- Germany
- Spain
- Ireland
- European Wind Integration Study

Q&A Session..... 4:45 – 5:00

Tutorial on Fundamentals of Wind Energy

Presenter Biographies

Sandy Butterfield

Chief Engineer

National Renewable Energy Laboratory

Sandy graduated from the University of Massachusetts with a Masters in Mechanical Engineering in 1977 where he studied under Bill Heronemus, famous for his floating offshore wind farm proposals in the early 1970s. He worked at Rocky Flats Small turbine research center as a test engineer, design reviewer and analyst till 1980 when he co-founded ESI, a wind turbine manufacturing company. As Vice President of Engineering he was responsible for the all aspects of design and manufacturing. After selling ESI in 1985 he joined the Solar Energy Research Institute (which later was renamed the National Renewable Energy Laboratory - NREL) as a research engineer.

His work at NREL has included aerodynamics research, testing, design reviews, contract management, manager of the applied research program, leader of the certification / standards program, Chief Engineer and leader of the codes group. Currently he is also working on offshore wind energy as well as leading NREL's Gearbox Reliability Collaborative. He has authored or co-authored more than 100 papers

Abraham Ellis

Sandia National Laboratory

Abraham graduated from New Mexico State University in 2000 with a Ph.D. in Electrical Engineering, and is currently employed by the Sandia National Laboratories. From 2001 to 2008, he worked in the Transmission Operations Department at Public Service Company of New Mexico, where he worked on large generator interconnection studies, transmission expansion planning and special projects related to transmission system performance and monitoring. Abraham is involved in various activities related to wind energy at the regional and national level. He currently coordinates Western Electricity Coordinating Council's Wind Generator Modeling Group and the IEEE Wind Generator Dynamic Performance Task Force. He also served as Chairman of the Modeling and Validation Work Group until July 2007. Abraham is a Senior Member of IEEE and is a registered Professional Engineer in the State of New Mexico.

Michael Milligan

Senior Staff Engineer

National Renewable Energy Laboratory

Michael Milligan works on the electric grid integration team at National Renewable Energy Laboratory, where he has analyzed various aspects of electricity supply related to wind energy since 1992. He has worked on issues such as the ancillary service impacts of wind generation, impact of balancing area combined operations on wind integration, impact of RTOs and ISOs on wind integration, the value of accurate wind forecasting, optimal selection of geographically disperse wind power plants, modeling wind plant variability, and reliability contribution and capacity credit of wind power plants. He is a member of the IEEE Wind Power Coordinating

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Committee and the NERC Integration of Variable Generation Task Force, has authored or coauthored more than 85 papers, reports, and book chapters, and regularly participates in technical advisory committees for wind integration studies around the U.S. Before coming to NREL, Michael worked in the electric utility industry, where he was involved with load forecasting, rate analysis, and electricity production simulation. He has M.A. and Ph.D. degrees from the University of Colorado, and a B.A. from Albion College.

Richard Piwko

Director, GE Energy
General Electric Company

Dick Piwko is Director of Power Systems Engineering with GE's Energy Applications and Systems Engineering group in Schenectady, NY. His responsibilities include management of large-scale system studies, power plant performance testing, control system design, analysis of interactions between turbine-generators and the power grid, and overall performance of large interconnected power grids. He has led numerous system design projects involving high-power electronics, including HVDC, static var systems, and thyristor controlled series capacitors. He recently contributed to GE's development of the Variable Speed Transformer (VFT), a new technology for transferring power between asynchronous power grids, and he is presently leading a project in China to solve a subsynchronous resonance problem at a 4800 MW coal plant. Mr. Piwko is a Fellow in the IEEE. He has served as chairman of the IEEE Transmission and Distribution Committee and the HVDC and Flexible AC Transmission Subcommittee. He is presently chairman of the IEEE Wind Power Coordinating Committee and a member of the NERC Task Force on Integrating Variable Generation.

Mark O'Malley

Professor
University College Dublin

Mark O'Malley received the B.E. and Ph.D. degrees from the National University of Ireland, Dublin, (NUID) in 1983 and 1987, respectively. After one year working in Irish industry he joined University College Dublin (UCD) where he is now the Professor of Electrical Engineering in the School of Electrical, Electronic and Mechanical Engineering with research interests in power systems and biomedical engineering. In 1994 he was awarded a Fulbright Fellowship and subsequently spent 7 months on sabbatical in the Department of Orthopaedic Surgery at the University of Virginia, USA. He is currently on sabbatical working with the U.S. Department of Energy's National Renewable Energy Laboratory.

In 1999 he was awarded a UCD President's Research Fellowship and a second Fulbright Fellowship and spent a one-year sabbatical in the Department of Electrical Engineering in the University of Washington, Seattle, USA. He has authored over 150 academic papers, graduated ten PhD students is a Fellow of the Institution of Electrical Engineers (IEE), a Fellow of the Institute of Engineers of Ireland (IEI), and a senior member of the Institute of Electrical and Electronic Engineers (IEEE). He is the director of the Electricity Research Centre (ERC) at UCD which is supported by all the major players in the electricity industry in Ireland including the Commission for Energy Regulation, ESB Networks, ESB Power Generation, ESB National Grid, Airtricity, Viridian and Cylon Controls. He acts as a consultant to the Irish electricity industry on a range of issues from electricity market design, grid integration of wind power and power

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system operations. O'Malley was a co-recipient of the 2008 UWIG Annual Achievement Award for his outstanding leadership in conducting the Irish All-Island Renewables Integration Study.

Dale Osborn

Transmission Planning Consultant
Midwest Independent System Operator

Dale Osborn is the Transmission Technical Director for the Midwest ISO. Wind generation issues, economic long range transmission expansion and voltage stability are his main focus. He serves as one of the Directors of UWIG for the ISO/RTO sector. He is vice chair of the IEEE Wind Power Coordination Committee and serves on the NERC Integration of Variable Generation Task Force. He serves on the DOE Peer Review for the Wind Energy Program. He is a registered engineer in the state of Nebraska. He worked for ABB for nineteen years in various positions involving Static VAR System design and performance verification, HVDC studies, and small SVC applications for industry including a wind farm. Previously, he worked for the Nebraska Public Power District for 10 years as the Manager of Power Resource and Transmission Planning. He has a BSEE and MSEE from the University of Nebraska at Lincoln.

Steve Saylor

Chief Electrical Engineer
Vestas

Steven Saylor, P.E is currently employed as Chief Electrical Engineer by Vestas Americas, a division of Vestas Wind Systems. Additionally, Steve is on the Adjunct Faculty of Portland Community College and Oregon Institute of Technology teaching courses on variable speed drive technology and wind energy systems design. While working for the Bechtel Power Corporation of San Francisco, and Portland General Electric he was assigned to the design, construction and operation of electrical power plants, mostly nuclear and coal-fired; as well as power transmission & distribution projects.

J. Charles Smith

Executive Director
Utility Wind Integration Group

Mr. Smith is a Senior Member of the IEEE Power Engineering Society, and a member of CIGRE, the International Council on Large Electric Systems. He received his BSME and MS degrees from MIT in 1970. He currently serves as the Executive Director of the Utility Wind Integration Group (UWIG), and is also the Managing Director of the consulting company Nexgen Energy. Previously, he served as President of Electrotek Concepts, a power engineering consulting firm. He has 37 years of experience in the electric power industry.

Pascal Storck

President
3TIER Environmental Forecast Group

Pascal serves as the President of 3TIER. He has background and experience in long-term hydrological forecasting, statistical methods, energy forecasting and assessment and system optimization. Dr. Storck received a bachelor degree in Civil and Environmental Engineering

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from Cornell University, a Masters in Civil Engineering through the University of Illinois-Urbana Champaign and a PhD in Civil and Environmental Engineering through the University of Washington.

Robert Zavadil

Vice-President and Principal Consultant
EnerNex Corporation

As a co-founder of EnerNex, Bob Zavadil is responsible for developing and overseeing the company's power system engineering consulting business. He has worked on electric power system issues for wind generation for over 15 years. Clients include wind turbine designers and manufacturers, project developers and operators, transmission service providers and ISOs, and research and development organizations including NREL, DOE, and EPRI. From 1989 until 2003, Mr. Zavadil served in various consulting and product development capacities for Electrotek Concepts and its parent company, WPT. Mr. Zavadil began his career in the electric power industry in 1982 as a special studies engineer in the Transmission and Distribution Engineering Division of the Nebraska Public Power District. Mr. Zavadil received a BSEE degree, with highest honors, from South Dakota State University. He is a member of the IEEE Power Engineering, Power Electronics, and Industrial Applications Societies, and serves as secretary of the IEEE PES Wind Power Coordinating Committee.