

Summary of the Tutorial on Fundamentals of Wind Energy
IEEE PES 2010 T&D Conference
New Orleans, Louisiana

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 evolving methods for transmission planning with energy resources.

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 Power Plant Overview*
- 3. Wind Power Plant Collector System Design*
- 4. Wind Plant Models for System Studies*
- 5. Wind Forecasting*
- 6. Power Grid Operations and Planning with Wind*
- 7. Capacity Value of Wind Plants*
- 8. Transmission Planning with Energy Resources*

**IEEE PES 2010 T&D Conference and Exposition
New Orleans, LA**

**Wind 101: Tutorial on Fundamentals of Wind Energy
Conducted by Wind Power Coordinating Committee**

Co-sponsored by:

**PSDP Committee, T&D Committee, PSO Committee, EDPG Committee,
PSACE Committee, and the Utility Wind Integration Group (UWIG)**

Contact: J. Charles Smith, Member (Charlie@uwig.org)

DATE: Monday, April 19, 2010

VENUE: TBD

DRAFT TUTORIAL AGENDA

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

**I. Wind Industry Overview8:15-8:45
(Robert Zavadil)**

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

**II. Wind Power Plants.....8:45-9:45
(Steve Saylor)**

- Turbine and Collector System overview
- Substation
- Reactive power
- Grounding

Morning Break.....9:45 – 10:00

**III. Wind Plant Collector System: Design and Protection Considerations10:00-11:00
(Ernst Camm)**

- Collector system design
- Grounding considerations
- Harmonic considerations
- Overcurrent protection considerations
- Overvoltage protection considerations

IV. Wind Plant Models for System Studies.....11:00-12:00
(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

V. Wind Forecasting.....1:00-2:00
(Jeff Lerner)

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

VI. Power Grid Operations and Planning with Wind.....2:00-2:45
(Richard Piwko)

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

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

VII. Capacity Value of Wind Plants.....3:00-4:00
(Michael Milligan)

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

VIII. Transmission Planning with Energy Resources.....4:00-4:45
(Dale Osborn)

- Transmission planning for capacity resources (reliability planning)
- Transmission planning for energy resources (economic planning)
- Transmission design alternatives
- Case study

Q&A Session.....4:45 – 5:00

Tutorial on Fundamentals of Wind Energy

Presenter Biographies

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 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

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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.

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.

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

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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.

Ernst Camm
Senior Engineer
S&C Electric Company

Ernst Camm has been actively involved in power system analysis associated with wind power plant integration, power system voltage stability, capacitor-switching transients, and power quality for almost 17 years. His current responsibilities include system analysis associated with the application of hybrid var compensators for improving power system voltage stability and for wind plant power factor control and fault ride-through, as well as wind plant engineering design studies, including short-circuit, protection and coordination, insulation coordination, and power quality studies. Ernst is the current chairman of the IEEE PES Working Group on Wind Plant Collector System Design and secretary of the Dynamic Performance of Wind Power Generation Working Group. He received his BSc (Eng) degree in Electrical and Electronic Engineering from the University of Cape Town, South Africa in 1984 and his MSEE degree from the Ohio State University in 1992.

Jeff Lerner
Director of Forecasting
3TIER

Jeff Lerner has served as the Director of Forecasting at 3TIER in Seattle since 2008. Jeff has over 15 years of diverse experience in the Atmospheric Sciences in academia, government, and industry. Jeff received his B.S. in Meteorology from San Jose State University in 1991, M.S. and Ph.D. from the Univ. of Alabama in Atmospheric Sciences. Jeff did his post doctoral research in Satellite Remote Sensing of Temperature and Humidity profiles for climate applications. He worked for the US Navy for 7 years in operational Numerical Weather Prediction modeling. He brings his operational and modeling experience to the renewable energy industry at 3TIER and oversees a team of 4 engineers and scientists focused on forecasting hydro, wind, and solar energy production.