EPRI | ELECTRIC POWER RESEARCH INSTITUTE

GEARED

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The Center for Grid Engineering Education

Bulk System Integration of Variable Generation

Course Description

This course will review topics related to variable generation (VG) integration into the bulk electric system. Increasing penetration of wind and solar (collectively, VG) can have significant impacts on bulk power system planning and operations. This includes the impact of transmission connected resources, but also the impact of the aggregate of large penetrations of Distributed Energy Resources on the bulk system. The impacts relate to a number of factors, including the variability and uncertainty associated with VG output over multiple time frames, the fact that these inverter based resources are non-synchronous to the electric power system and therefore behave differently from typical resources, and the locations of these resources, either far from load at locations with good wind and solar resources, or located on the distribution system such as with rooftop PV. These resources also have close to zero marginal costs, impacting on the system economics. Due to these factors, areas experiencing or expecting to experience high VG penetration will require significant changes to how they plan and operate the bulk system.

Beginning with an overview of the expected impacts, the course will introduce participants to the main processes in bulk system operations and planning being impacted by wind and solar power, with examples from across the world on existing experiences and studies. This includes resource planning and resource adequacy, transmission planning, power system scheduling and dispatch and operational reliability. For each individual area, methods to more effectively integrate renewables into the system will be described, based on latest research efforts and integration studies. This will include methods currently in use and those likely to provide support to effectively integrate VG in the future. Aspects such as wind and solar forecasting, the use of smart inverter capabilities to support bulk system reliability and grid codes and standards will be covered.

Who Should Attend

Utility engineers and others focused on bulk system functions will benefits from this course, including transmission and resource planners, grid operators and others in similar functions. Individuals involved in the renewable policy and planning activities will learn about potential integration impacts and solutions for managing VG in a cost effective and reliable manner.

Registration Information

PDH Available: 12 hours

Registration Fee: $1,200 per person

- 20% discount for organizations with three or more attendees
- 25% discount for government employees (non-utility)
- 25% discount for university professors*
- 75% discount for graduate students*

*University IDs required to qualify for professor or graduate student discounts.

Students need to bring: laptops or tablets to access online resources and to follow class notes. Wi-Fi access is provided. Lecture slides will be provided electronically in PDF format.

For More Information

Amy Feser, afeser@epri.com, (865) 218-5909

Course Instructors

Aiden Touhy, atuohy@epri.com

Anish Gaikwad, agaikwad@epri.com

Deepak Ramasubramanian, dramasubramanian@epri.com

Meet the Instructors

Aidan Tuohy is a Senior Project Manager in the Grid Operations, Planning and System Studies group at the Electric Power Research Institute (EPRI). He has worked with EPRI since October 2010, and is the program lead on their research program on integration of variable generation. His main focus is on studies and R&D projects related to the planning and operation of power systems with large amounts of wind and/or solar generation. In particular, he has done a significant amount of work in the area of flexibility requirements for systems with high variable generation penetration and the commitment and dispatch of generation, transmission, demand and other flexible resources in systems with high penetrations of variable generation. Prior to working at EPRI, Tuohy worked on the International Energy Agency's Grid Integration of Variable Generation project. He received his Bachelor of Engineering degree in electrical/electronic engineering from University College Cork, Ireland in 2005. He completed his doctoral degree at the University College Dublin Electricity Research Centre in 2009.

Mr. Anish Gaikwad is a Principal Project Manager in Grid Operations and Planning Group in the Power Delivery & Utilization Sector at EPRI. As a Project Manager, his job duties are to manage and provide technical leadership to EPRI research activities related to transmission planning. At present, he is leading EPRI's research efforts in the area of risk-based planning. He is working on developing advanced planning tools to study the impact of variable generation and loads. He coordinates EPRI's efforts on Transmission-network Contingency Analysis and Reliability Evaluation (TransCARE) software which is a unique tool that can be used for performing risk-based planning. His other research activities focus on load modeling and model validation for transmission planning studies. Mr. Gaikwad's other areas of interest are performing analytical studies related to load modeling, interconnection studies, transient studies, insulation coordination, harmonic studies, distribution reliability and service quality, improving distribution efficiency, impact of Plug-in Hybrid Electric Vehicles on distribution circuits and other areas related to transmission and distribution engineering. He received his Bachelor of Electrical Engineering degree from Regional Engineering College in Nagpur, India in 1997 and a Master's of Science in Electrical Engineering from Mississippi State University in 2002.

Deepak Ramasubramanian is an Engineer/Scientist II at the Electric Power Research Institute (EPRI) in the Grid Operations and Planning Group of the Power Delivery and Utilization Sector. Deepak joined EPRI in 2017 where his work is in the area of modeling, control and stability analysis of the bulk power system with recent focus on the associated impacts of large scale integration of converter interfaced generation. Deepak received his Ph.D. degree in Electrical Engineering from the Arizona State University, Tempe, USA in 2017 for his dissertation on assessment of the impact of converter interfaced generation and load on grid performance. Prior to that, he received his M.Tech. degree in Power Systems from the Indian Institute of Technology Delhi, New Delhi, India in 2013 and his B.E. degree in Electrical and Electronics Engineering from the PES Institute of Technology, Bangalore, India in 2011. He is an active member of the IEEE Power and Energy Society and participates in the NERC and WECC industry wide load and renewable energy modeling and performance task forces. He is a recipient of the North American SynchroPhasor Initiative (NASPI) Outstanding Graduate Student Award and the Power System Operation Corporation (POSOCO) Power System Award.

Course Outline

Day 1 (Full Day)

- **Intro to changing power system and challenges**
- **System operations with wind/solar**
  - Unit commitment/dispatch
  - Wind/solar forecasting
  - Frequency control
  - Operating reserves
  - Stochastic unit commitment and probabilistic methods
  - Market operations
- **Transmission planning and bulk system operational reliability**
  - Generic models for wind/solar
  - Model validation
  - Risk based planning and scenario building
  - DER models for bulk system studies
  - Load Modeling w/DER

Day 2 (Half Day)

- **Resource planning and flexibility assessment**
  - Capacity adequacy of VG
  - Flexibility needs
  - Energy storage for bulk system integration
  - Demand response
- **Other topics**
  - Restoration and renewables
  - System protection
- **Wrap up**

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