Addressing the Educational Needs for Engineers for Planning, Designing and Operating Present and Future Electric Grids

Short Course Offerings

The following courses are part of a growing library of courses offered under the GridEd family of educational training activities. These courses are compact to provide state-of-the-art understanding in key areas of a rapidly changing electric system environment. Courses can be taken independently or can be grouped to meet objectives of a particular training need. Some of the listed courses are under development.

Applications of Smart Inverter Technology – This course investigates the core theory, modeling, and analysis behind smart inverter technology and its application on the power system. Students will learn relevant characteristics of inverter operation, including topologies, modulation, maximum power point tracking, grounding, and protection. From the foundational understanding, "smart" functionality will be discussed, including control of real and reactive power and low-voltage ride-through. Advanced methods of control such as frequency-watt and volt-Var control will also be covered. The course will then expand to cover the impacts of these techniques on distribution system behavior and PV hosting capacity. Theory-based discussions will be supplemented with simulation, experimental results, and relevant case studies. Recent developments in codes and standards, including UL1741 and IEEE1547, with an emphasis on solar PV, will also be included.

Bulk System Integration of Variable Generation – (Under Development) This course identifies the challenges and benefits of integrating uncertain variable generation into the bulk electric system. Topics include considerations for grid planners and operators including voltage support and frequency stability, determining operating reserve and flexibility requirements, solar forecasting technologies and methods, as well as various metrics being used for bulk system integration.

Business Case Analysis for the Electric Utility Industry –This course presents and demonstrates the foundations for utility investment decision making from three related cost/benefit perspectives:

1. *Societal* – Does the change in how energy services are used and supplied result in a better use of scarce societal resources (employing a conventional cost/benefit analysis framework)?

2. *Utility* – Quantifying how costs are incurred to accommodate new supply technologies and determining the costs incurred to serve new electric load (using the utility Revenue Requirements framework).

3. C*ustomer* – Characterizing how rate structures and enabling technology influence customers' decisions to adopt new electric technologies, and how the induced usage changes affect all other customers (employing a customer behavior framework).

The course will provide participants with a general understanding and specific subject area knowledge of how electric utilities plan and operate a power system to meet multiple objectives. The learnings are reinforced through case studies focused on evaluating smart grid technology investments, accommodating distributed generation resources, and assessing new electricity uses. Course participants can expect to gain a broader enterprise perspective, benefiting the company and their career. These fundamentals will be applied to regulated and unregulated investor-owned utilities, municipal electrics, co-ops, and other government entities.

Data Communication Technologies and Applications – **(Under Development)** The use of communication systems and data transfer is a rapidly changing field in electric utility industry. This course will focus first on the fundamental communication technology options such as WiFi, powerline carrier, radio, among other technology choices. System interface designs based on platform approaches will also be explored. Modern metering methods and products will be examined as the needs for metering technique, end-use metering, and other practices are evolving. Other advanced automation practices such as including distributed energy resources (DER), advanced metering Interface (AMI), the OpenADR protocol and other demand response (DR) protocols will be

considered. Data formats and structures will be evaluated to determine suitability and best practices will be provided. Size and frequency of information packets will be examined.

Distributed Generation Interconnection on Radial Distributions Systems – This course will review basic topics on DG that is connected to inverters and synchronous/induction generators, as well as radial and network power distribution. It includes material on steady-state voltage and power flow issues, protection challenges, and temporary overvoltages. It will discuss the current IEEE 1547 and UL 1741 requirements and will end with a discussion of the engineering issues that arise as penetration levels increase.

Distributed Generation Technologies – A survey of distributed technologies, including characterizing the solar resource, photovoltaics materials & electric characteristics, photovoltaics (PV) systems, CSP solar, wind power systems, fuel cells, and distributed fossil generation systems. The economics of these systems will also be evaluated.

Distribution System Reliability – (Under Development) The course will focus on distribution reliability. Typical reliability indices are considered distribution capacity planning, loss of load expectation, expected energy not supplied, other reliability indices, computational methods of those indices and introduction to commercial reliability software. In addition, causes of interruptions will be considered. Rious modeling and analysis methods is explored. The course closes out by examining several case studies.

Electric Power Distributed Systems – This course focuses on the designs, performance criteria, equipment characteristics, and operational practices associated with electric power distribution systems. Students will learn about proven designs and concepts, while also receiving training on the latest trends and emerging power distribution technologies.

Electricity Markets – Course participants will learn about the electrical power system infrastructure and reliability operation, and the locational marginal cost based pricing mechanism underlying the wholesale electricity market design. Additional topics include market settlement, the capacity and Financial Transmission Right (FTR) markets, and management of generation portfolios by the load serving entities. Impacts from integrating intermittent renewable generation, energy storage and demand-side resources will also be discussed. Further, the CWRU has developed an online electricity market simulator that allows course participants to play realistic market clearing scenarios while acting as market participants. As a key component of the course, the interactive market simulation exercises supplement the course lectures with hands-on learning experience. Course participants will retain online access to the market simulator tool for six months after the course.

Energy Storage Technologies, Applications and Integration – This course is part of a series of courses developed and offered by GridEd to address several evolving forces that will alter the fundamental operating characteristics of the electric grid, transforming it from a one-way central supply structure to one that has bidirectional, flexible power flows resulting from the integration of energy storage systems. This course focuses on energy storage technologies and applications for transmission and distribution connected systems. Students will learn about the policy, cost, and technical challenges facing the wider use of energy storage and what can be done to address those challenges. Additionally, considerations for energy storage project development and deployment will be discussed.

IEEE 762 – This course covers the principles of IEEE Standard 762, "IEEE Standard Definitions for Use in Reporting Electric Generation Unit Reliability, Availability and Productivity" and explores how performance standards need to be adopted for variable generation.

Predictive Analytics and Optimization for Electric Power Distribution Systems – This course is one in a series of several courses developed and offered by GridEd to address the evolving forces that will alter the fundamental operating characteristics of the electric grid, transforming it from a one-way central supply structure to one that has bidirectional power flows resulting from distributed energy resources (DER). Self-generating consumers will alter the design requirements for the electric distribution system.

This course focuses on applications of predictive analytics on smart electric power distribution systems and the use of Large Scale (Big) Data Analytical methods and their application to electric distribution system analysis and design. The basics of big data analytics and the electric power distribution system will be introduced. Four data-driven applications in electric power distribution systems will be studied closely. These include 1) Distribution system topology identification using smart meters data; 2) Distribution system power flow and state estimation; 3) Distributed energy resources adoption forecasting; and 4) Load and demand response forecasting. This is a first course in developing techniques to analyze the distribution system in a Big Data format. These techniques will be applied in subsequent courses to analyze such industry challenges as electricity markets and including design approaches to distribution system operator (DSO) managed electricity market. Six problem sessions and case studies are included in this interactive short-course.

Power Quality – This short course relates to electric power quality, the characteristics of maintaining rated electrical parameters in a power system. The topics discussed are the main points that encompass this field in the world today including voltage sags, harmonics, momentary events, interference, and waveform distortion. These topics are studied in terms of definitions and theoretical bases; measurement and instrumentation; circuit analysis methods; standards; sources of problems; and alternative solutions. An important objective of the short course is to acquaint the attendee with the most recent developments, issues and solutions in electric power quality engineering, especially issues related to renewable resource integration.

Unbalanced Distribution System Analysis – This course covers the analytical frameworks necessary to analyze unbalanced electrical power networks beginning with distribution sub-system fundamentals followed by topography for lines and load modeling, in consideration for overhead and underground systems.

Utility Applications of Power Electronics – Utility Applications of Power Electronics is a senior undergraduate/graduate level course taught at UNCC. It has been offered regularly once per year for two years. Over the summer of 2015, Prof. Manjrekar added three lectures and associated exercises to the course material on the following topics:

- Grid Tied Power Electronic Converters
- Photovoltaic Power Conversion
- Stationary Energy Storage Interface
- Grid Connected Electric Vehicles

Semester Courses

Fundamentals of Electric Power Systems – The purpose of this course is to provide engineers and analysts an introduction to electric power systems analysis. It is offered in two parts: 1) fundamental components and 2) analysis methods.