On the Design of a Graduate-Level Cross-Disciplinary Course on Smart Grids

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***Abstract*—Development and maintenance of smart grids require power systems engineers to have a good understanding of auxiliary fields like computer networks and vice-versa. This paper discusses a graduate level course and its offered topics towards meeting such cross-disciplinary training objectives. Furthermore, this paper discusses the lessons that can be learnt from such a graduate level course for undergraduate eduction in smart grids.**

I. Introduction

According the US Department of Energy "Smart Grid generally refers to a class of technology people are using to bring utility electricity delivery into 21st century using computer based remote control and automation [1]. This initiative not only requires power engineers to have a better understanding of auxiliary fields like signal processing, controls, information technology, and communication networks, but also needs experts in the auxiliary fields to understand the basic operations of power systems. There is great need in industry for such cross-trained professionals to meet challenges in modernizing the power grid.

Training professionals and students in smart grids needs a creative curriculum that crosses traditional divisions based on disciplines. For example, students taking advanced courses in the power systems area traditionally have an electrical engineering background as do students in the control systems and telecommunications fields. However, students involved in computer networking and communications require a computer science or computer engineering background. This divergence results in many challenges in co-education of such professionals and students. This paper presents the thought process behind a graduate level course the authors plan to offer jointly in the near future at their institution. The first author comes from the background of computer networking and communication while the second author has a power systems background. Specific aspects discussed are the course outline, selection of multi-disciplinary topics for this course, challenges envisioned, lessons for undergraduate education. Though power systems courses may have taught communications as a sub-topic before, the authors believe theirs is one of the first approaches to co-teach such a course with an audience that does not have much in common in terms of background.

II. Course Outline, Topics, and Execution

This course is intended to cross-train graduate students in communications and networking or control systems about the power systems area, and vice-versa. The planned graduate course will be divided into four parts: power systems, computer networking and communications, environmental and economic issues, and controls. The two main thrusts of the course are power systems and computer networks. The selection of topics was based primarily on two considerations. The first consideration was ensuring power systems students are exposed to basic techniques from computer networking, and computer networking students understood the power grid and its fundamentals. The second consideration was ensuring the instructors have adequate expertise on the chosen topics to involve students in research. There was also the additional consideration of adding breadth which was accomplished by adding topics in control theory and its applications, and environmental and economic issues. These additional topics will offered through guest lectures by instructors with expertise in those areas.

The topics in the power systems area emphasize what the authors feel are emerging and important research topics, with a fair concentration in the area of distribution systems. The topics in the computer networking and communications area emphasize communication requirements, enabling of consumer participation in energy delivery, and information security and privacy. These topics in the networking are in emerging research areas of the computer science community and deemed to be of great importance in realizing the smart grid vision. The topics on environmental and economic issues add a focus on sustainable energy solutions and expose the students to issues that relate to the expected impact of smart grids. To provide a third dimension apart from power systems and networks, topics in control systems will be covered that can have direct applications towards modernizing the power grid. Table I shows the complete course outline for the planned graduate course.

The intended audience for this course would be from the following three groups: (i) Power Systems students working on grid automation, integration of renewables, or impacts of EVs, (ii) Computer Networking students interested in a career where their networking skills are applied in the power

TABLE I
OUTLINE OF TOPICS FOR THE GRADUATE COURSE AT WICHITA STATE UNIVERSITY TITLED "ELEMENTS OF SMART GRID".

1) Power Systems
   a) Introduction to Power Systems
   b) Power system transients and stability
   c) Outage management
   d) Signal processing in power systems
   e) Smart sensors / synchrophasors / telemetry
   f) System performance / reliability
   g) Estimation theory
2) Computer Networking and Communications
   a) Introduction to Communication Networks
   b) Communication requirements for smart grids
   c) Existing smart grid communication standards
   d) Hybrid communication systems for smart grids
   e) Advanced Metering Infrastructure
   f) Information security and privacy
   g) Network protocol development and performance evaluation for smart grids
3) Environmental and Economic Issues
   a) Distributed energy sources / microgrids / demand response
   b) Environmental impacts
   c) Economics of alternative fuels
4) Controls (Application based)
   a) Decentralized / distributed control
   b) Multi objective optimization
   c) Real time control

systems area, and (iii) Control Systems students interested in developing control solutions for power system applications. Initial offerings will place greater emphasis on the distribution system of the power grid.

Designing the course execution to keep students from diverse backgrounds engaged can be challenge. As a result it was decided to start off with basic introductory lectures in the two major thrust areas before advanced topics are covered in either of them. This is expected to provide an early common platform for all students to subsequently understand and appreciate advanced topics. The power systems part starts with an introduction/refresher that included basic concepts like circuit theory for computer networking students who may be out of touch. Similarly, basic computer networking concepts and how the Internet works are covered for students from other disciplines.

All course assignments and projects are assigned as groups that were to include one student from each of the major backgrounds like power systems, computer networks, and control systems. This enabled one student, well-versed in the area under consideration, to be the lead in an area-specific assignment who helped students from other backgrounds catch up. For projects, this enabled the formulation of multi-disciplinary problems that required students from diverse backgrounds to join together in proceeding towards a solution.

III. IMPLICATIONS FOR UNDERGRADUATE EDUCATION

Though the course described in this paper was at the graduate level, there are important lessons for planning and teaching a course in the area of smart grids for the undergraduate level. An expected outcome from the graduate level course is the preparation of course materials on smart grids. These materials will be prepared from a cross-disciplinary perspective that encompasses computer networking, communications and signal processing, control systems, and power systems. Currently there are few textbooks on the topic of smart grids; the authors believe that these course materials can eventually form the basis for developing a textbook in this multi-disciplinary area at the undergraduate level and lay the foundation for introducing an undergraduate course in the area of systems engineering focused on smart grids.

In the graduate course, students who have prior mastery over an area sit together to apply their skills and learn new techniques in the smart grid area. This is a bottom-up approach expected to have challenges due to the lack of "a common language for communication". A better approach might to start top-down by introducing a course on smart grids early during their undergraduate education with little or no pre-requisites. Subsequently, the students can take advanced undergraduate courses in their area of choice that they can apply and build upon in the smart grid area. For example, an undergraduate student who learns about smart grid and its applications in the basic course, can subsequently decide to learn more about the communication networks that enable such applications or the power systems fundamentals that characterize these applications.

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[1] *Smart Grid*, Department of Energy, available: http://energy.gov/oe/technology-development/smart-grid