AC 2012-4963: AN INDUSTRIAL-ACADEMIC PARTNERSHIP FOR AN EYES-ON ELECTRICAL ENERGY EXPERIENCES CLASS

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Introduction:

Declining enrollments in power engineering over the last decade and the anticipated loss of engineers through retirements from the power and energy workforce have focused attention on the need for a rapid increase in the power and energy engineering workforce. Furthermore, there are a wide variety of challenges facing the nation in power and energy, including changing mixes of energy, development of alternative energy sources, creation of a Smart Grid, minimizing environmental impacts of energy, and others. To address these challenges will require engineers across multiple disciplines, but all sharing a fundamental core of knowledge on power and energy.

In response to this need for a power and energy engineering workforce, with advice and guidance from an Industrial Advisory Board (IAB), the authors were part of a team that established two Power and Energy Certificate programs, one for undergraduate students and one for graduate students. (See Holloway, et al[1] for additional information about the certificate program.) Both certificate programs are multidisciplinary across engineering, including electrical, mechanical, chemical, civil, computer, materials, mining, and biosystems engineering. All students take a core of common classes to give them a base of knowledge across power generation, transmission and distribution, economics, and public policy. There were 434 students enrolled in the power and energy classes in Fall 2011 and 149 students have had two or more power and energy related courses over a two year period. Our Industrial Advisory Board emphasized to us in the development stages that it was valuable for the students graduating from the program that they should also have a broader vision of the energy area than just what they would normally learn in textbooks. They indicated it would be important for the students to have actually visited and learned about various facilities related to energy production, distribution and use and other energy usage related sites.

This paper will discuss the first offering of a three-credit-hour course during the spring semester 2011 which was developed for the students to obtain this eyes-on learning. In order to expand the learning opportunity in the course and to make it more than simply a series of tours, the course was designed so the students would do background work to gain an understanding of what they would be visiting, and then actually visit the facility and talk with operators. At the conclusion of each visit the students would then write a journal of their visit to each regional power and energy related facility. Assessments from the students about the course and its learning opportunities will also be presented. The class represents a potential model for exposing students to industry facilities in the form of a learning laboratory and also exposes the students to industry experts who can speak on the issues and technologies in today's power industry. This paper will also discuss some of the challenges in developing and executing the course which may be issues that occur for other institutions considering replicating such a course.

Development of the Experiences Class:

As part of a grant from the US Department of Energy, The University of Kentucky developed the Power and Energy Institute of Kentucky (PEIK) which has a major objective of developing the workforce in the electrical power industry. This is being accomplished by developing coursework to award a Power and Energy Certificate at both the undergraduate and graduate levels. The material to be covered in this certificate program was developed in coordination with an Industrial Advisory Board (IAB) which consisted of individuals representing various aspects of the electrical energy industry in the region. The IAB included representatives of investor-owned and cooperatively-owned utilities, design engineering firms, manufacturing firms, industrial associations, and the state energy cabinet.

One of the strong recommendations of the IAB during the development of the program was that the students receiving the certificate should have a better understanding of what actually existed in the field rather than just having all the coursework be classroom related. Therefore, a graduate level class was developed in which students would be able to have a field experience where they would be able to see a number of energy generation, distribution and use facilities as well as associated pollution reduction and control facilities and various energy equipment manufacturing facilities. The course objective was that at successful completion of the course the student should be able to understand and describe: a) conventional and renewable electrical generation sources, b) electrical distribution systems, c) methods of controlling electrical power generation, distribution, and storage, and d) several methods commonly used to increase the efficiency of electrical energy use.

The IAB was initially given a list of various categories of types of facilities which might be visited based upon an assumption that the facilities would be located within a day's bus ride of the university. This list was collectively reviewed by the IAB in a meeting. They discussed the various categories and gave input on the importance of each type facility to be visited and their ability to host or facilitate such a tour. Following that meeting a list of places to visit and contact information was developed using the resources of the IAB members to find and make the appropriate contacts at the facilities. Since 93% of the electrical energy produced in the state[2] is with coal-fired steam boilers there is an emphasis on coal fired generation plants and the associated equipment related to pollution control.

Tours were arranged to visit the following types of facilities:

Energy Generation Facilities:

- Coal Fired Steam Generation:
    - Circulating Fluidized Bed Boiler
    - Supercritical Coal Fired Boiler

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- Open Cycle Dual-fuel Turbine (gas/oil turbine)
- Nuclear plant (steam generation) (Under construction)
- Landfill Gas Turbine
- Low-Head Hydroelectric Plant
- Large-Scale Pumped Water Storage
- Large-Scale Wind Farm
- Photovoltaic Site: a campus facility with rooftop solar power.
- Shale-gas fracking

Pollution Prevention and/or Control Facilities

- Coal gas scrubber
- Carbon capture and sequestration
- Ash pond

Electrical Control, Distribution and Use

- Smart-Grid demonstration
- Electrical system control and dispatch center
- Large military complex energy management and control center
- Geothermal district heating and cooling system
- Net-zero-energy house

Electrical Equipment Manufacturing

- Distribution transformer manufacturing

Class Logistics:

Schedule - Beginning the second week of the semester, each Friday, 17 students and the instructor would board a small bus at 8am to visit at least one of the sites. The sites were selected so that we could make the visit in a single day – typically returning mid-to-late afternoon. The exception was one visit when we left late Thursday afternoon after classes, stayed overnight near the first site, visited three facilities and returned late Friday evening.

Typically we would arrive at the site, spend 30-45 minutes getting an overview from the facility personnel of what was to be seen, then split up into smaller groups to visit the site. After 1-2 hours visiting the facility we would then return to a central location to answer any general questions which may have come up during the tours.

Assignments - In order for this course to be more than just a tour each week and to prepare students for what they were going to be visiting, there was an assignment before each visit. This would be either to write a short paper or review a reading assignment covering the technology which was to be visited. After each visit the students were required to write a short journal entry which described the technology which they viewed. Typically the students made extensive use in their journals of photos which they had taken during the tours.

Student Assessment – The grading for the course consisted of class attendance and participation (70%), papers and quizzes (15%) and journal entries (15%). A short quiz covering the reading material was given on the bus before every visit when a reading assignment was given. This was the first assessment of the students understanding of what they were going to visit. The first part of the bus travel time was spent going over the quiz and helping the students understand things which were not comprehended from the readings.

Tour Hosts - There was a great deal of enthusiasm by those facilities contacted to participate in the program once they understood the objectives of the course. The facility personnel were very willing to spend time with the students explaining the technologies existing at their facilities. The students were typically very prepared to ask specific questions about what they were going to see or the technology that was involved. The tour hosts with engineering backgrounds appeared to have a greater rapport with the students than those with no formal technical training. Usually the tour hosts were also quizzed about what they expected from new hires and/or what important traits or skills it took for employees to succeed in their business.

Student Evaluations of Facilities Visited:

While we limited the class size to twenty students, seventeen students were enrolled in the initial class during the spring of 2011. At the end of the semester the students were asked to evaluate each of the site visits from 0-5 based upon the importance of the visit (with 5 most important). A summary of the student evaluations is presented in Figure 1. The students rated all the tours very highly.

Clarification is needed on some of the ratings however. The wind farm tour was the lowest rated tour. It should be noted that after traveling 3 ½ hours on a sunny day the bus ascended several hundred feet to reach the series of wind turbines situated on a mountain top. By the time we reached the top of the mountain we were in the middle of a heavy cloud cover and could not see the nacelle - only the tips of the turbine blades as they got close to the ground could be seen. The highest rated visit was to the Bellefonte Nuclear Power Plant. This TVA plant was started in the 1980s but had never been completely finished -- thus no nuclear fuel had been brought to the site. Since the facility was “mothballed” when it was nearly completed but didn’t have fuel loaded we were able to fully tour the facility – including going into the primary containment vessel, looking into the reactor which had the head removed and getting a close-up / hands-on view of empty fuel rod bundles which were used to train operators of other nuclear plants. The students perceived this as a ‘once-in-a-lifetime” experience and thus many of them rated this as one of the highlights of their college experience.

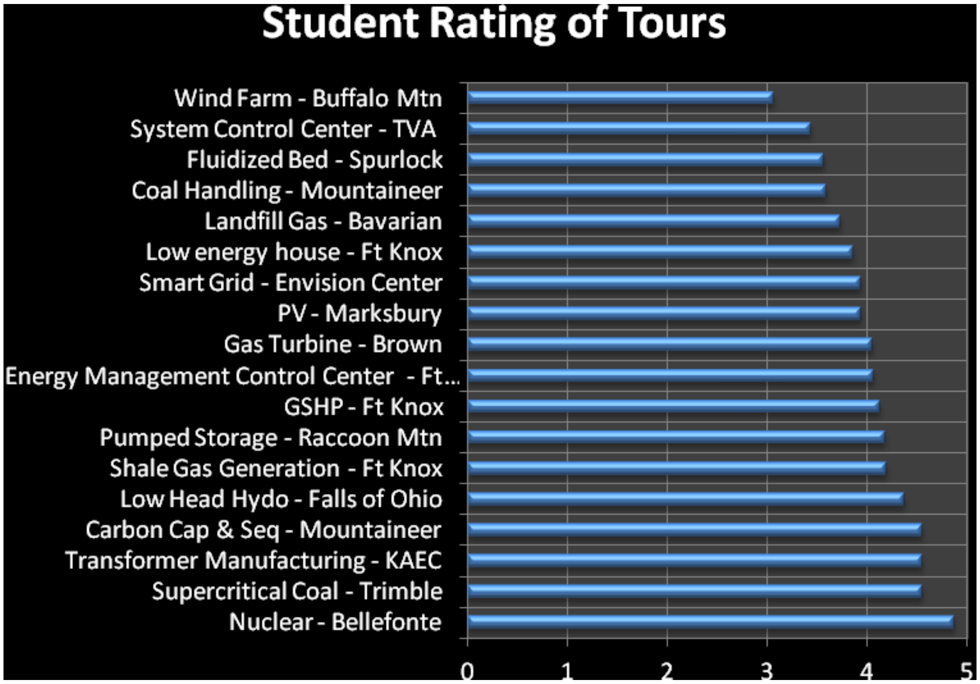

Figure 1. Student Ratings of Tours

The students were also asked to enumerate the three least-important and the three most-important sites which added to their learning experience.

Only the nuclear facility and the low-head hydro facility were missing from being on any student's list of least-important sites. The only reason which can be proposed for the low-head hydro site not being included on any list is that this visit occurred when the plant was undergoing extensive maintenance. One of the turbines was disassembled and the students could actually see parts of the disassembled water turbines. This emphasized the importance of being able to see the actual working components and not just the exterior housing of the equipment.

Every site visited during the semester was listed by at least one student as being one of the three most-important visits. This illustrates the importance of having a wide variety of facilities when there are multiple engineering disciplines involved. For example, we had discussion of many types of engineering, from the metallurgy of the turbine blades, to the complicated control strategies of the power distribution system, to the thermal energy flows of a net-zero-energy building. This wide variety also was important to illustrate that the power and energy industry is very interdisciplinary and many different types of engineers are needed.

Antidotal feedback volunteered from the students several months after taking the course has indicated that this course added a tremendous experience to their education and they wished other schools had this opportunity.

Challenges and Opportunities for Improvements:

In order to successfully deliver a course such as this there are several significant challenges which must be recognized and addressed.

Scheduling – The biggest challenge was getting the students scheduled so they could participate. In order to include visits to the wide portfolio of facilities, this class essentially required an entire day of class time for the entire semester due to the travel required to the diversity of geographic locations. Students participating in the PEIK certificate program are required to take a series of courses. We have arranged for these classes to be offered Monday and Wednesday or Tuesday and Thursday so the students can have the entire Friday free to take this class. Establishing this schedule in a university which typically has Monday/Wednesday/Friday classes required considerable discussions with scheduling personnel. We discussed offering the class in a compacted format where we would travel extensively during a couple of weeks before the semester started or a week before classes started and during spring break. The students did not like either of these options. From experience with a couple of trips during this class in which we covered three different sites, it was evident that there was a saturation or visual stimulus overload after just a couple of visits per day. It is believed that attempting to compress the travel into a shorter timeframe would detract from the learning experience.

It was a significant challenge to arrange the class visits on Fridays over the semester. It required several of the facilities to initially be flexible in their tour dates until all the arrangements could be made. Even then, due to extreme weather conditions of snow and extended rain periods a couple of proposed tours were canceled (coal mine and strip mine reclamation site) since a four-wheel drive vehicle rather than a bus would be needed to reach the site. Several of the facilities also were short-staffed on Fridays and thus had to schedule people to give the tours.

Another scheduling challenge was for the faculty member who taught the class. It essentially required one full day of each week during the entire semester plus the time which was required to make all the tour arrangements and the normal class development time. This exceeds the time typically allotted to a three-credit-hour class and it also restricts other classes taught by the faculty member to be on a Monday/Wednesday or Tuesday/Thursday schedule. The faculty member was able to rearrange his other class' meeting times and the grant allowed for some payment to cover the additional teaching load.

Appropriate Reading and Background Material – A reading assignment was given each week to explain the technology existing at the site of the upcoming visit. Students in this course came from a wide range of engineering disciplines. Therefore finding the correct graduate class level of material for all the students to read and understand was a challenge. In particular it was difficult to find material which was detailed enough so the students would get a good overview of what they were going to see but not so in-depth that the students would get overwhelmed or so simple they would not be challenged.

Adequate Student Assessment and Evaluation – Student assessment is a tremendous challenge in a course like this. The grading of the students needed to be more than just a record of the attendance of the student on the site visits. An effective evaluation of what the student learned from the visit is very difficult to measure. While attendance was a major portion of the grade (70%), it was felt that the students should be prepared to understand what they were visiting and then they should be able to describe what they had visited. Therefore there was a pre-visit quiz covering the reading material describing what they were to be visiting (15% of grade) and after the visit they each wrote a journal describing their visit and the technology they had seen (15% of grade). The evaluation criteria are being slightly changed for the next offering of the class to add "class participation and tour questioning" to the "attendance" evaluation section. While this has been challenging to some of the students, it is believed that the students should be taking more initiative in asking questions during the tours so they will be more engaged in active learning about what is being described.

Travel Expenses – A bus had to be used on all of the tours except one where we visited an on-campus facility. Therefore there were considerable class transportation expenses which are not normally funded by the University. The cost for the bus was approximately $500 per week. The DOE grant paid for the bus transportation plus provided the hotel lodging for the one overnight trip. All meals were paid by the students with the exception of a couple of tours where the host also provided a meal for the students. It is expected that the IAB will be requested to provide funding for the class when the grant funding ends.

Appropriate Presentations at Site – Each of the sites were informed of the makeup of the audience to which they were presenting. Several of the presenters were engineering college graduates and they understood what the class was attempting to accomplish. Therefore they made excellent presentations explaining the unique engineering aspects of the facility. Unfortunately at other facilities, the students were given more of a sales presentation about the attributes of the technology or were given more of the operational techniques of the equipment and were not able to adequately answer some of the more technical questions.

Security Clearances – Several of the sites visited required significant security clearances. This was not a major issue – even for the individuals holding student visas. However it required a significant amount of lead time and the willingness of the students to release personal information.

Eyes-On Personal Visits versus Electronic Visits – During the initial development of the course there were discussions about whether or not the students needed to actually physically visit the facility or if video presentations describing the facility would be sufficient. It may be argued that very well done, polished videos describing the facilities and their operation would go a long way to meeting the objectives of this course. However, it is believed that the personal interactions with the presenters, actually visiting the sites to put the size and scope of the equipment in perspective, and seeing, hearing, feeling and smelling the operation of the equipment far outweigh the saving which might be obtained by conducting the course through video presentation. This was verified by one example. There was a professional production presented describing the carbon capture and sequestration facility before we made the site visit. All the students quizzed thought that the video presentation was not nearly effective as making the site visit – even though it was an eight-hour bus ride. They indicated that they were not able to get a true perspective of the size, scale and investment in the facility by just looking at the screen.

Summary:

This paper presents the development and the execution of a graduate level course designed to give students a field experience with a number of energy generation, control, distribution and use facilities as well as associated pollution reduction and control facilities and various energy equipment manufacturing facilities. Also presented are a listing of the sites visited, the student evaluations of these visits, and some of the unique challenges which must be addressed in successfully delivering this type of course.

Acknowledgement:

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[1] Holloway, et al. 2012. A Multidisciplinary Power and Energy Engineering Program. ASEE 2012 Conference Paper.

[2] http://www.eia.gov/cneaf/electricity/st_profiles/kentucky.html, Table 5. 2009 Data.