AC 2010-648: MULTI-INSTITUTIONAL APPROACH TO ENGINEERING EDUCATION

Ilya Grinberg, Buffalo State College

Ilya Grinberg graduated from the L'viv Polytechnic Institute (L'viv, Ukraine) with an MS in EE and earned a Ph.D. degree from the Moscow Institute of Civil Engineering (Moscow, Russia). He has over 30 years of experience in design and consulting in the field of power distribution systems and design automation. He has over 30 published papers. Currently he is Professor of Engineering Technology at Buffalo State College. His interests are in the field of electric power distribution systems analysis, design automation, and systems engineering.

Mohammed Safiuddin, State University of New York, Buffalo

Mohammed Safiuddin received the B.E. (Electrical) degree from Osmania University, Hyderabad, India in 1959 and the MSEE degree from the University of Illinois in 1960. Later he received the MBA and Ph.D. degrees from the University at Buffalo [SUNY], in 1971 and 1982 respectively. He is currently Research Professor (part-time), Advanced Technology Applications, in the Electrical Engineering Department of University at Buffalo [UB]. He is President of STS International, a technology service firm he established in September 1985. His areas of technical interests cover static power conversion and optimal control systems as applied to industrial processes, energy conservation and energy management. He has been awarded 10 patents in this field and has published numerous technical papers.

Chilukuri Mohan, Syracuse University

Chilukuri K. Mohan is Professor and Chair of the Department of EECS at Syracuse University, with a Ph.D. (1988) from SUNY at Stony Brook. He has authored/co-authored two books and over 150 research papers and book chapters, in various areas of Artificial Intelligence. He serves on several international conference committees, an IEEE Task Force on Swarm Intelligence, and on the editorial board of the Journal of Applied Logistics.

Steve Macho, Buffalo State College

Steve Macho completed a BS at St Cloud State University, and M.A. & Ed.D. in Technology Education at West Virginia University. He worked at the Los Alamos National Laboratory, New Mexico Highlands University, and is currently an Assistant Professor of Technology Education for at Buffalo State College. He became a member of the Oxford Roundtable in 2008 and plans to present another paper there in 2010.

Multi-Institutional Approach to Engineering Education

Introduction

Many specialized areas of study exist for which there is a definite but small market in the industrial world. The size of this market may preclude the development of economically viable and self-sustaining programs of study worthy of long-term investment by a single institution, in the context of limited resources. Investment in such a program is fraught with the risk of large downward swings in enrollment due to market forces and cyclical variations in the industries relevant to the program. However, the development and implementation of such programs of study is often essential to the national infrastructure and economy. Hence the need to leverage limited resources available at multiple institutions is addressed in this paper. The broad background is first considered and the proposed approach is illustrated with a case study.

The instructional process in post-secondary education consists of multiple steps, including decisions and implementations of:

1. Course outcomes
2. Course content
3. Instructional materials
4. Delivery methodology
5. Assessment and evaluation
6. Mentoring of students.

Mentoring is the unique cornerstone of the learning process that requires individualized interactions between instructors and students. However, the remaining five steps can utilize the services and expertise of individuals in other locations, thereby increasing the effective use of resources at multiple educational institutions.

Course outcomes and content are often based on the expectations of multiple stakeholders (including instructors of other courses), although sometimes not explicitly stated, or modified during the course delivery, or ignored. Accreditation requirements and curricular standardization efforts imply considerable redundancy in content and outcomes at different institutions. In other words, the efforts in this context are needlessly duplicated at multiple institutions. Besides, these activities do not generally require frequent revisions, and can be agreed upon by discussion and consensus among responsible individuals at different institutions.

The third step (development of instructional materials) is again often duplicated, with essentially identical sets of slides, notes, and handouts being prepared at multiple institutions. Significant savings can be achieved by pooling the resources available at different institutions. The most common example of this is textbooks and materials associated with them used as needed at multiple institutions.

The fourth step concerns delivery methodology. Instructors have varied skills in course delivery, with substantial dependence on their prior familiarity with the course material. The expenditure of considerable effort in planning the delivery of instructional materials has great payoffs in terms of educational outcomes for students, but is sometimes infeasible for faculty members involved in multiple other activities. Methodologies that can provide high-quality instruction from other academic institutions would be valued by any institution.

The fifth step (assessment and evaluation) is generally performed offline (evaluating tests, assignments, reports, etc.), and the effort can hence be distributed among multiple institutions, although some aspects of assessment require physical interactions in the classroom (which can sometimes be conducted online to a limited degree using resources that exploit the internet). Although evaluation standards currently differ among institutions, it would be useful to have more standardized evaluations at different institutions, perhaps performed by the same individual and using the same methodology.

From the above analysis it is clear that education in niche areas can be conducted in a robust manner by sharing instructional resources among multiple institutions, with variations in market demand not leading to "extinction" of educational programs. Effective and efficient interface with stakeholders outside the academia is also paramount.

Area of application and proposed approach

One of such niche areas gaining prominent attention is the next-generation electricity grid, known as the "smart grid" or "intelligent grid," which is expected to address the major shortcomings of the existing grid. To allow pervasive control and monitoring, the smart grid is emerging as a convergence of information technology and communication technology with power system engineering. It is clearly a multidisciplinary area in need of retooling its current approaches to education and training.[1]

The American Recovery and Reinvestment Act of 2009 (ARRA) includes support for implementation of Smart Grid programs as well as other initiatives to modernize our existing electrical power infrastructure. These efforts are critical to achieving national goals of renewable energy development, electric vehicle adoption, and energy efficiency improvements. However, besides technology developments for this, we need to address existing skills shortage and aging workforce in power industry. It is, therefore, critical that training of current workforce and educating new cadre of power engineering professionals be addressed through a joint effort of all stakeholders; the academia, the industry, the government, the professional societies, and last but not the least, the individual professional.

Besides traditional areas typically taught in power curricula, additional technical areas to be included are: advanced measurements and sensing technologies, signal processing and telecommunications, adaptive control, cyber security techniques, energy efficiency, more knowledge on power electronics, as well as policy and economics. Such educational and training programs require collaboration amongst all stakeholders. Needless to say that such an important task is better handled by a consortium represented by the above mentioned constituents in order to develop well coordinated array of certificate and degree programs. Such a consortium is being formed in New York State and consists of leading universities, comprehensive colleges, community colleges, power utility companies, electrical equipment manufacturers, and State agencies. Using a system's approach as depicted below, this paper addresses various organizational and methodological aspects of the consortium as well as challenges faced.

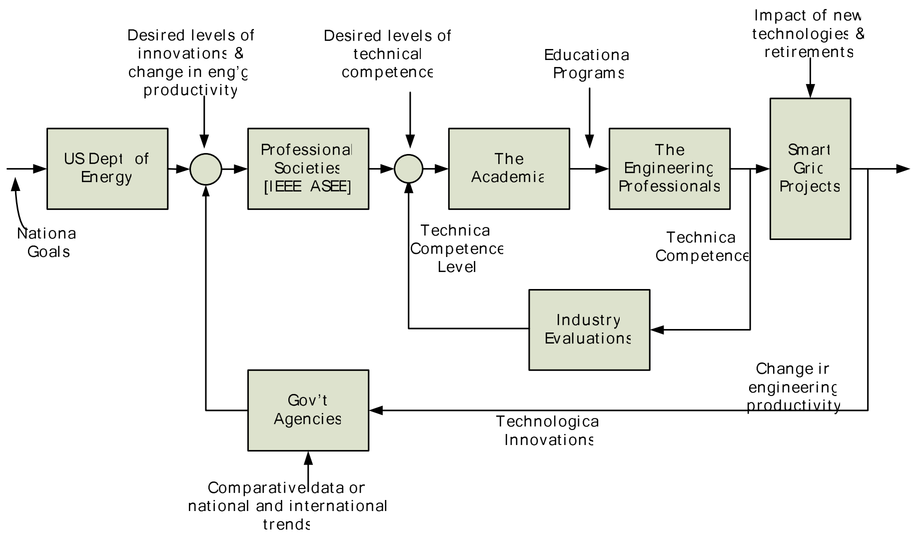

Fig.1. System's Approach to Roles and Responsibilities of Various Organizations

Figure 1 represents a high-level model of interrelations between individual professional, educational institutions, industry, and governmental agencies. This model also represents the roles and responsibilities of the various organizations and their points of interface.

An inner loop deals with technical competence of the workforce. The profession, through its societies (IEEE, ASEE and others) establishes qualitative and quantitative objectives for the competency levels, the subject matters, and the quality criteria for the educational programs as input signals to the universities and educational institutions. The industry provides the feedback to the academia on technical performance of the graduates. The outer loop produces reference levels of desired objectives for the education and training programs based on reference and feedback provided by governmental agencies. The governmental agencies interface with the professional societies and do not get directly involved in the detail educational programs or university-industry interface itself.

In general, training and education for the smart grid includes several levels:

1. Consumers
2. Trades and labor
3. Technical and technician
4. Engineering and science
5. Management/supervisory

Proposed curriculum development model calls for modular structure. A module is equivalent to a discipline-specific program appropriate to one of the levels above.

Curriculum for typical module includes all required components and is in compliance with ABET requirements. It has all provisions for continuous improvement. Conditions block includes such factors as administration, institutional, internal, and external support. Input includes educational objectives that are formulated by program constituents with participation of steering oversight board and steering oversight committees at each level. Figure 2 represents typical curriculum lifecycle for an individual program, such as Smart Power Engineering, Electric Power Fundamentals, etc. It has a number of program outcomes and course outlines[2].

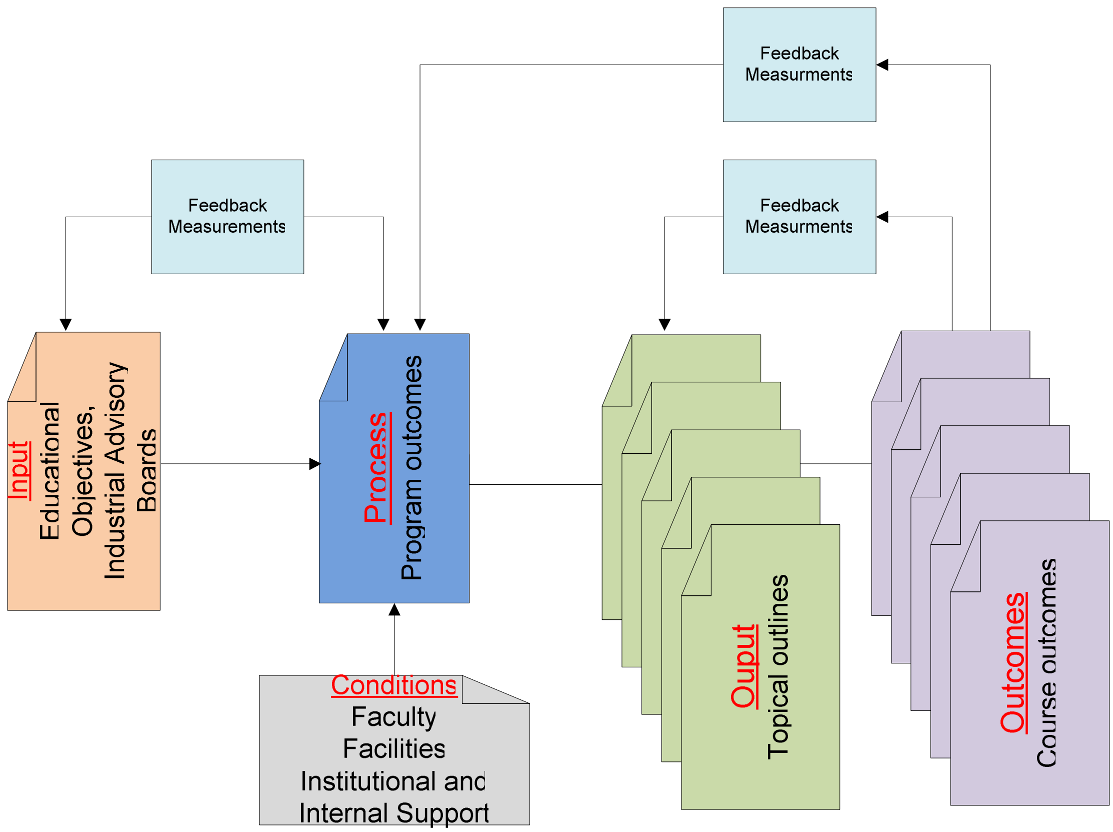

Fig.2. Curriculum Development for Typical Module

Figure 3 represents curriculum structure of interrelated modules delivered either at one or at multiple institutions. Administration and delivery infrastructure are unified and linked to conditions in Fig. 2. Such a structure with distributed modules and unified administration and delivery network reflects the concept of the consortium by providing flexibility, integration of expertise, and oversight.

Curriculum should be modular with possibilities of using modules at various levels. For example, in some cases more sophisticated module from engineering level may be delivered for technician's level or less sophisticated module may be delivered to management level.

It would then be possible to maintain same general outlines and sequencing within different providers (schools) but they could customize their programs by using modules at the level they see fit (for example, offering more in-depth and sophisticated modules in the areas they want to concentrate more, while keeping certain modules at a basic level).

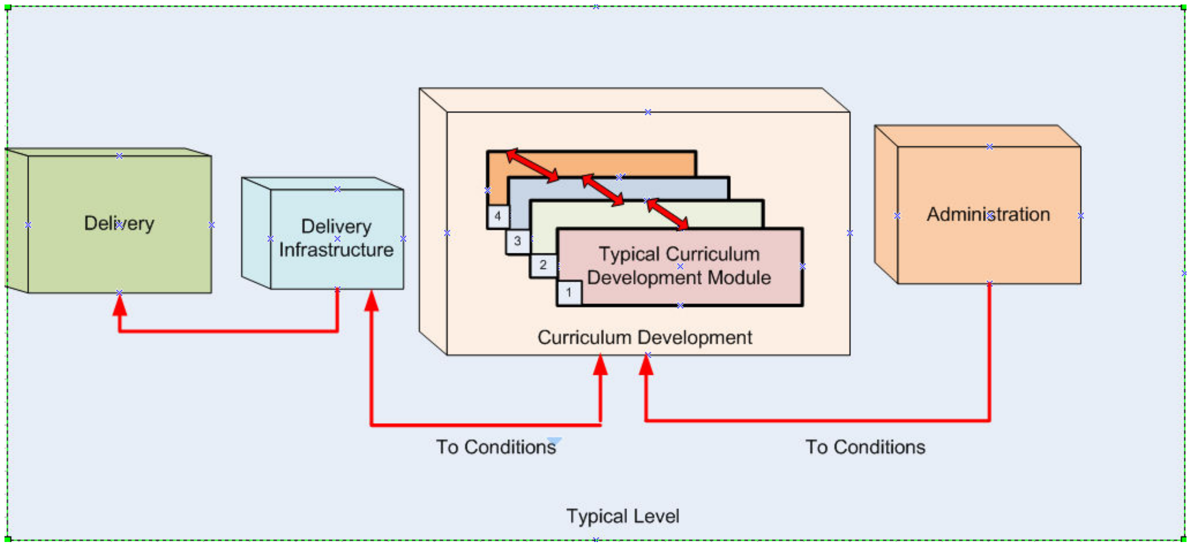

Fig.3. Typical Level

Addressing the challenges

In September 2009, Department of Energy issued a call for proposal DE-FOA-0000152 Recovery Act – Workforce Training for the Electric Power Sector seeking applications that will support and greatly expand job creation and career advancement opportunities within the utility industry and the electric power system equipment manufacturing sector. Two types of applications were specified:

Topic A. Developing and Enhancing Workforce Training Programs for the Electric Power Sector with subtopic Strategic Training and Education in Power Systems (*STEPS*) and Topic B. Smart Grid Workforce Training. The objective of *STEPS* is to support educators at universities and colleges (including community colleges) in developing new curricula and training activities in areas most relevant to the achievement of a next-generation electric power workforce with solid technical understanding and innovativeness to address our energy challenges and to ensure U.S. global leadership. Applications were sought which would develop cross-disciplinary electric power systems training programs at the university and college-level, that lead to degrees or certificates spanning the breadth of science, engineering, social science, economics, and other topics needed by scientists, engineers, innovators, entrepreneurs, and industry leaders as the traditional power system transforms into a national, clean-energy smart grid[3]. Power and Energy Society of the IEEE laid a significant groundwork identifying action plan, objectives, priority goals, and proposed action published earlier[4].

To address such an ambitious challenge, dealing with multidisciplinary issues, it is desirable to combine potential of several entities from academia, equipment industry, electric utility companies and government agencies. In response to the cited DE-FOA, such a collaborative consortium was formed in New York State to develop and deliver a proposal in STEPS subcategory. Soon after the Department of Energy (DOE) announcement, NY State Energy Research and Development Authority (NYSERDA) called for a meeting of interested parties in order to identify potential participants and collaborative alliances. About 60 participants from academic institutions, utilities, industry, labor organizations, and other State agencies discussed various strategies, identified their interests, and developed plan of action. Some of the valuable support the State is providing is:

- Share information gathered statewide regarding benefits and potential opportunities to leverage them;
- Assist in gathering data of percentages of the workforce retiring in the next several years in key power grid job categories;
- Assist/facilitate creation of internships. Identify Statewide and regional resources thus identifying partnership opportunities;
- Assist with Consortium's evolving mission so that it complements the needs of business and education;
- Work towards obtaining a State matching funds to successful FOA 152 applicants to further strengthen applications and meet cost share requirements.

The importance of such an initiative by the State agency is difficult to underestimate as it played a catalytic role in subsequent actions. Soon after this important meeting, a group of academic institutions located in fairly compact geographic region, as well as one of the largest power utility companies, initiated several teleconferences to build the momentum following the statewide meeting. A collaborative consortium resulted to address a comprehensive spectrum of knowledge and skills from the basic understanding of the concept and logistics of the "Smart Grid" to the technical requirements associated with the design, security, operation of communication and control devices and various other new technologies.

To ensure the quality and appropriateness of the courses and curricula, the consortium engages a regional utility industry partner, National Grid USA, as well as utility, alternative energy, building systems manufacturers and representatives of workforce and economic development organizations. Subject matter faculty experts are coordinating with industry to review job-knowledge analyses of the various industry job families and career ladders, and compare them to the learning outcomes of the curricula to insure alignment with the new knowledge-based and skill-based competencies required of the Smart Grid implementation.

This project proposes to achieve the following objectives:

1. Develop and deliver innovative smart grid enhanced curriculum beginning September 2010.
2. Develop and deliver a comprehensive, regional Distance Learning offering of associate, undergraduate, certificate, master and doctorate degrees beginning May 2012.
3. Expand Distance Learning curricula to meet national workforce needs by completion of project in April 2013.
4. Establish an innovative and experience-rich distance learning system incorporating best in class courses from all partner institutions and facilities.
5. Create a specialization in Smart Grid cyber-security.
6. Create a specialization in Smart Grid alternative energy integration.
7. Incorporate aspects of project management, public policy administration and public communications into the curriculum.
8. Leverage micro-grid and demonstration project research on one of the campuses for the

benefit of student experience.
9. Expand distance learning format
10. Deliver degree graduates to protect jobs within the existing utility and manufacturing workforce, to redeploy displaced workers from transitional industries and to secure meaningful employment for graduating youth.

To support preparation of the proposal, NYSERDA provided assessment data of training needs and gaps that will drive development of degree programs in the project scope.

In the light of the recognition that no single institution participating in the consortium has all the requisite expertise to deliver effective Smart Grid curricula at all levels, submitted proposal envisages a framework within which the participating academic institutions would be involved in collaboratively developing and delivering courses and curricula. The participating institutions include four Universities (Syracuse University, University at Buffalo, University of Rochester, and Clarkson University) that award undergraduate and graduate degrees, a four-year comprehensive college (Buffalo State College) with strength in power engineering, and a community college (Onondaga Community College).

All these institutions lie within relatively short driving distances, providing the opportunity for students at any of these institutions to visit any of the other institutions on occasion, as may be required for specific coursework or projects that necessitate physical presence at a laboratory or Smart Grid installation. Furthermore, strong long-standing collaborations have existed with the National Grid USA, provider of electrical and gas utilities, with offices in Syracuse, NY, including a new Smart Technology Center with laboratory facilities that are expected to be made available for workforce training and use by students enrolled in Smart Grid curricula. In addition, National Grid USA has committed to provide the guidance and expertise to develop relevant and practical curriculum and laboratories utilizing the expertise of their principal engineering staff.

These academic institutions plan to offer Smart Grid-specific training programs with a novel multi-institutional curricular structure. The courses to be offered by each institution will depend upon their strengths and expertise, and will be delivered online to students from other participating institutions as well as personnel who have registered for Smart Grid retraining at any of these institutions. This would optimize use of the distributed nature of our faculty resources, with institutions complementing each other rather than duplicating the coursework. For administrative purposes, courses will be “cross-listed” at each institution, and the “primary” faculty teaching a course at one institution will be considered to be Adjunct Faculty at the other institutions. Each student will choose one “host” institution where the student will register for courses, whether in a matriculated program or as an un-matriculated student seeking certification.

Course offerings and content will be proposed by the primary faculty members, with reviews and feedback being provided by the relevant faculty from the other institutions. For courses requiring hands-on laboratory interaction, each academic institution with the needed facilities will utilize the services of a “secondary” instructor whose primary role is to facilitate laboratory work. Students from other institutions (without the laboratory facilities) will be given the option of traveling weekly to one of the laboratory sites during an academic term. A primary/secondary instructor will be made available on a Saturday by the institution with the laboratory, to facilitate instruction to working professionals who may not be able to travel out of their city during the weekday. An appropriate distribution of course tuition fees between the student's host institution and the institution that provides the laboratory facility is envisioned. The primary consideration in setting up these procedures is that any student registered for a Smart Grid certificate or degree program at any institution should be able to access the faculty, instructional, and laboratory facilities at any other participating institution, as well as the facilities of the industry partners of this collaborative proposal.

The academic institutions participating in this project have had past success in online delivery of course materials, hybrid instructional models that combine some classroom presence with substantial online content delivery components, and inter-University collaborations that facilitate the education of students using instructional materials from multiple Universities. However, to the best of our knowledge, this would be the first time that such a strategy will be followed using as many as six academic institutions, with tremendous flexibility and student choices, making the prospect of developing the new generation of Smart Grid engineers a reality rather than a dream. The laboratory and faculty resources available at any single institution are relatively small and are not by themselves sufficient to educate a required number of Smart Grid personnel, but when viewed as a united front, together they provide unparalleled capability and expertise that can address the expected shortfall in Smart Grid personnel. If this pilot model is successful, we envisage a longer term plan in which other academic institutions (nationwide) would also participate, subject to the availability of nearby laboratory facilities, or the possibility of student travel to a well-equipped institution for approximately a week of intensive laboratory training.

Concluding remarks

The current model of the engineering educational process, focused on autonomous and independent conduct of all steps of the instructional process at a single institution, works well in many areas of study, but is inadequate to address education in niche areas, which can best be addressed by co-operative use of resources available at multiple institutions. This paper has proposed a framework for this new model, with an example focused on Smart Grid education and training programs to be conducted at multiple institutions in upstate New York. This model is applicable to several other niche areas of engineering, particularly those calling for multi-disciplinary strengths.

The results of these efforts should yield improved opportunities for training the next generation of Smart Grid workforce at all levels. Although this goes contrary to the traditional model where each institution hoards its own resources, our institutions are committed to overcoming bureaucratic obstacles to help address the expected nationwide shortage of Smart Grid practitioners and developers[4]. Collaboration among these institutional, industrial, and government partners is ironically a "test-run" for establishing the collaborative working environment the Smart Grid would need to exist within. The Smart Grid will require groups that have not historically worked together to integrate many job functions.

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