CURRICULUM IMPROVEMENTS IN POWER ENGINEERING

Efraín O'Neill-Carrillo[1], Agustín Irizarry-Rivera [2], Miguel Vélez-Reyes[3]

Abstract *— The Power Engineering Group at the University of Puerto Rico-Mayaguez (UPRM) has implemented several strategies to improve its curriculum and meet new ABET accreditation criteria. Strategies include the revision of course contents, integration of laboratory practices to courses, and a more prominent role of undergraduate research and power electronics in the power engineering curriculum. Courses are being updated to include contemporary topics while keeping fundamental engineering principles. A recent grant by NSF will support on-going efforts to create laboratory practices that would connect the teaching of theoretical principles to actual implementations. Participation in the Center for Power Electronics Systems, a NSF Engineering Research Center, has given UPRM the opportunity to expand course offerings and undergraduate research in power engineering. An important outcome of this curriculum improvement is to motivate students to take an active role in the learning process.*

Index Terms — Accreditation preparation, research and the classroom, undergraduate research experiences

INTRODUCTION

Electric energy systems have experienced dramatic changes in the last twenty years. The advent of sophisticated generation control, microprocessor-based relays and improved power electronics devices that process high levels of energy are just a few examples of the transformation of the energy business. Nowadays, deregulation of electric power generation poses another challenge to engineers everywhere in the U.S. The recent power crisis in California is a good example of how vital energy systems are in maintaining economic growth [1]. This is also an example of the type of challenges faced by power engineers, not only in California, but everywhere in the world [2,3]. There is a need at all levels in industry, from large utilities to small consulting firms, for prepared professionals that can deal with today's energy challenges at the utility side as well as the customer side. It is important to improve the education of engineers in areas related to energy in order to ensure a pool of qualified professionals that will face today's energy challenges. Nevertheless, there has been a dangerous trend at U.S. universities to reduce or even close power engineering programs [2,3].

Over the years, the Power Engineering program at the University of Puerto Rico-Mayagüez has prepared engineers to deal successfully with industry challenges. However, new technologies, changing industry needs and new educational paradigms have motivated the Power Engineering group to revise its curriculum and assess the effectiveness of its teaching methods. Students should be prepared in both classical and new areas allowing them greater flexibility when choosing a career path and making them attractive candidates to potential employers.

An important objective of this curriculum improvement is to motivate students to take an active role in the learning process. Improving course content and format spark student interest in the subject matter while providing professors with an assessment tool. Laboratory experiences and undergraduate research make students active participants in the learning process, and improve their understanding of power engineering principles and applications. Enhancing the role of power electronics provides students with a broader and up-to-date preparation that increases their chances of obtaining a challenging job in power engineering. All these strategies have been structured and will be used to comply with new ABET accreditation criteria [4].

PROGRAM DESCRIPTION

UPRM and the ECE Department

The University of Puerto Rico, Mayagüez Campus (UPRM) was founded in 1911 as a land-grant college under the provisions of the Morrill-Nelson Act. Today, over 765 professors and researchers; 1,175 supporting staff; and approximately 13,000 students are part of UPRM's academic community. The institution is fully accredited by the Middle State Association of Schools and Colleges, of which it has been a member since 1946. UPRM is among the top ten institutions in the nation in undergraduate engineering enrollment. Over four thousand six hundred (4600) students register each year in the university's engineering programs. UPRM is also the largest source of Hispanic engineering graduates in the nation. The university graduates 700 engineers per year, or 25% of all Hispanic engineers nationwide. There are five engineering degrees offered: chemical, civil, computer, electrical, industrial and mechanical engineering. In Table 1,

[1] Efraín O'Neill-Carrillo, Electrical and Computer Engineering Department, PO Box 9042, Mayagüez, PR 00681-9042 oneill@ieee.org
[2] Agustín Irizarry-Rivera, Electrical and Computer Engineering Department, PO Box 9042, Mayagüez, PR 00681-9042, agustin@ece.uprm.edu
[3] Miguel Vélez-Reyes, NSF Center for Power Electronics Systems (CPES), UPRM, PO Box 9042, Mayagüez, PR 00681-9042, mvelez@ece.uprm.edu

Authorized licensed use limited to: Univ of Texas at El Paso. Downloaded on January 22,2021 at 02:56:01 UTC from IEEE Xplore. Restrictions apply.

Electrical and Computer Engineering students represent 30% of all undergraduate engineering students.

The Department of Electrical Engineering (EE) was founded in 1928. The EE Master of Science program was established in 1967, while the Computer Engineering Program (CpE) was added in 1981. The EE program has been accredited by ABET since 1960 and the CpE program since 1994. The Electrical and Computer Engineering (ECE) Department presently has 48 full time faculty members, over 1300 undergraduate students (including 500 Computer Engineering majors) and 70 graduate students. The bachelor's degree is a five-year, 168 credit-hour program. There are five areas of specialization in Electrical Engineering (EE): Applied Electromagnetic, Control, Communications, Electronics and Power Engineering. There is a committee for each specialization area, formed by the professors in each area, and a person that coordinates educational and research efforts in each committee.

TABLE I
DISTRIBUTION OF STUDENTS PER ENGINEERING PROGRAM

Program	Number of students
Chemical Engineering	736
Civil Engineering	770
Surveying	167
Electrical Engineering	875
Computer Engineering	503
Industrial Engineering	628
Mechanical Engineering	848
TOTAL	4,527

Power Engineering

Contrary to the national trend of reduced programs, UPRM has a strong power engineering program, in terms of number of professors and students. Ten professors teach power engineering courses to 200 students each semester. An average of 47 students graduate each year with a power engineering minor (at least 19 credits in power engineering courses). Table 2 lists power engineering courses.

The revision of the power engineering program began with the definition of two options within the program: power systems and power electronics. The undergraduate power engineering curriculum includes thirteen undergraduate courses as well as undergraduate research experiences and special topics offered to students each year in power engineering. All EE students attend two introductory courses in power engineering INEL 4103 (Power System Fundamentals) and INEL 4405 (Electric Machines) plus a one credit-hour laboratory on energy conversion. These courses represent topics common to both power systems and power electronics options. Figure 1 presents the sequence in which power engineering students take courses for both options. Besides power engineers, students from electronics and control areas usually attend power electronics courses.

TABLE II
UNDERGRADUATE COURSES IN POWER ENGINEERING AT THE UNIVERSITY OF PUERTO RICO-MAYAGÜEZ

COURSE	TITLE
INEL 4103	Introduction to Power Systems
INEL 4405	Electric Machines (Energy Conversion)
INEL 4406	Electric Machines Laboratory
INEL 4407	Electrical Systems Design I
INEL 4408	Electrical Systems Design II
INEL 4409	Illumination Engineering
INEL 4415	Power System Analysis
INEL 4416	Power Electronics
INEL 4995	Professional Practice
INEL 4998	Undergraduate Research
INEL 5406	Transmission and Distribution Systems
INEL 5407	Computer Aided Power System Design
INEL 5408	Electric Motor Control
INEL 54xx	Design Projects in Power Electronics
INEL 5415	Protection Design for Electrical Systems
INEL 5995	Special Topics in Power Engineering

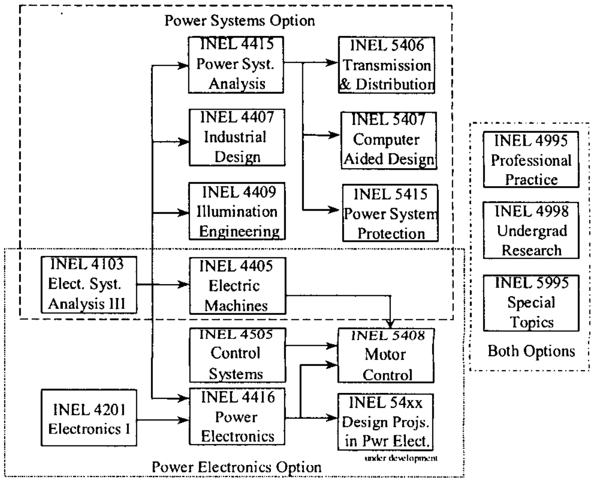

FIGURE 1
SEQUENCE OF POWER ENGINEERING COURSES

INTEGRATING LABORATORIES TO COURSES

The restructuring of power engineering undergraduate courses at UPRM combines teaching the fundamental, most relevant concepts and providing a hands-on experience in a scaled, functional version of a power system. A grant from the NSF CCLI program (DUE-0088619) will support the acquisition of equipment to implement laboratory exercises within courses. This grant will increase teaching resources, which will translate into better course contents and class time management. This will improve the quality of the power engineering program. By providing a physical connection between theory and practice, students will be more motivated to learn and apply energy concepts. The under-

Authorized licensed use limited to: Univ of Texas at El Paso. Downloaded on January 22,2021 at 02:56:01 UTC from IEEE Xplore. Restrictions apply.

graduate power electronics and motor control courses are included in this project. This represents increased resources for power electronics education at UPRM. This project is expected to have a significant impact on the number of students attending courses and undertaking undergraduate research projects.

The Power Engineering curriculum is being revised in order to integrate laboratory practices to courses. Fundamental concepts or areas have been identified for each course. Laboratory practices that support those concepts will be developed and implemented. A vital component in this process is the use of technology, e.g., specialized engineering software for analysis and computer simulations. Well-structured laboratory practices, besides improving technical expertise, will enable students to improve their communication and teamwork skills. An important part of this effort will be the integration of cooperative learning techniques in a laboratory environment, particularly the roles within a team.

These practices will help the ECE Department meet the new accreditation criteria from the Accreditation Board of Engineering and Technology (ABET). Adding a laboratory component to undergraduate courses, would enable students to engage in the solution of engineering problems in a way that would directly meet nine out of eleven ABET guidelines [4]. These guidelines are mentioned in a latter section.

ROLE OF UNDERGRADUATE RESEARCH

An important component of the ECE curriculum is undergraduate research. For over eleven years, the ECE Department has successfully administered the Industrial Affiliates Program (IAP). This program supports undergraduate research projects in which students work closely with a Faculty mentor to solve an engineering problem or improve/develop modeling tools [5]. Industrial sponsors have a chance to evaluate the projects during the Annual IAP Meeting, in which students present the results and findings of their work. This is a very valuable experience for students, professors and industry.

Students get to work side by side with faculty and graduate students, improve their communication skills (besides the oral presentation, they have to write progress and final reports), and learn how engineering theory is applied to solve problems. Faculty members get a chance to influence to a higher degree the careers of students, encouraging them to excel in their jobs or to continue graduate studies. It is also a chance for faculty to integrate research and teaching, a model proposed by many scholars to balance the many duties professors have [6]. Finally, industry benefits from having a closer link to UPRM since they are supporting the preparation of potential employees, and can give feedback or influence the direction and contents of the curriculum. Students participating in an IAP project can receive a stipend or up to three credits for the course INEL 4998 Undergraduate Research.

IAP projects in Power Engineering

An example of an IAP-sponsored project is the development of virtual worlds to explore electric power grids or plants [7]. In this project two undergraduate students participated in the design and implementation of two virtual worlds: a QuickTime VR model of a power plant, and a VRML model of a power grid (both used in electric power systems courses). The purpose of developing these educational aids was to provide an economical and accessible way to help students relate and differentiate the mathematical description of a device and its actual appearance. In a sense these aids provide a virtual laboratory experience. Dr. Irizarry-Rivera was the project advisor.

Last year, three undergraduate students participated in the project "Development of Tools for the Study of Chaotic Behavior in Power Electronics" directed by Dr. O'Neill-Carrillo. The project comprised a thorough literature review on applications of chaos theory in power electronics, a short course in chaotic dynamics and the development of Spice modules for the simulation and analysis of chaotic behavior. Emphasis was given to DC-DC converters. A report was written and converted into a conference paper [8].

Five students are currently participating in the project "Harmonics in Computer Loads and Electronic Ballasts". Dr. O'Neill-Carrillo is the project advisor. The main objective is to determine harmonic pollution from computer and lighting loads at UPRM's ECE Building, and provide recommendations on ways to improve power quality at the building. This project is funded through the Industrial Affiliates Program. Other IAP projects in power engineering have included power electronic implementations, motor control techniques and applications of computers in power systems.

ROLE OF POWER ELECTRONICS

Power electronics deals with the use of semiconductor devices to convert energy from one form to another (ac-ac, dc-dc, ac-dc, dc-ac). Power electronic devices provide an efficient way to process and control energy [9]. This is a multi-billion dollar industry that produces enabling technologies for applications ranging from wireless communications and computers to high power devices. Power electronics have been part of the Power Engineering Curriculum at UPRM for the last seventeen years. Both graduate and undergraduate research work in power electronics have also been performed at UPRM since the 1980s. The widespread use of power electronics in power systems, industry demands and opportunities for research funding have motivated the Power Engineering faculty to enhance the role of power electronics within the curriculum. It has been defined as a formal option, together with power systems. Courses in the power

Authorized licensed use limited to: Univ of Texas at El Paso. Downloaded on January 22,2021 at 02:56:01 UTC from IEEE Xplore. Restrictions apply.

electronics option includes an introductory course, motor control and a design course in power electronics.

Undergraduate Power Electronics Course

During Spring 2000, Dr. O'Neill-Carrillo tried a different approach in teaching UPRM course INEL 4416 "Introduction to Power Electronics". Emphasis was given on applications, from dc-dc power supplies to HVDC transmission. Instead of three partial exams, only two were given. A group project was assigned instead of the third exam. Elements from the research process were included in class. The class project was a literature review on various topics in power electronics. All projects included Spice simulations or a significant design component. Examples of topics assigned were trends in motion control, photovoltaic and wind energy sources, and inverter topologies. This approach will again be followed for the Fall 2001 semester.

Design Course in Power Electronics

The basic course in power electronics deals primarily with characteristics and analysis tools for different circuit topologies. A capstone design course in power electronics does not exist at UPRM. The creation of INEL 54xx "Design Projects in Power Electronics" will fill that void. A graduate student is collaborating with Dr. O'Neill-Carrillo and Dr. K. Venkatesan in preparing the material for the course. Since power electronics is part of the power engineering curriculum, designs will include applications of both rectifier and inverter topologies. There will be a comprehensive group project complemented with seminars on design techniques. The course will be offered for the first time on Spring 2002.

Center for Power Electronics Systems

The UPRM branch of the Center for Power Electronics Systems (CPES), is the first National Science Foundation Engineering Research Center at the University of Puerto Rico. CPES is a consortium of universities lead by Virginia Tech that includes UPRM, RPI, University of Wisconsin-Madison and North Carolina A&T.

CPES has played a key role in supporting power electronics activities at UPRM for the last three years. These activities have been a driving force for change in the areas of academic revision of curriculum, collaboration with industry, teaching and research resources. Papers from the basic course in power electronics were published as a local UPRM CPES report. CPES is currently supporting the creation of the design course described earlier. Participation in CPES has given UPRM the opportunity to expand course offerings in power engineering. Distance learning via videoconferencing or taped-classes have been offered for the last two years from other CPES member universities to Senior and graduate students in power electronics [10].

UPRM participation in CPES has also allowed Faculty to expand the scope of their research work and provided resources for graduate students. Over 25 undergraduate students and 7 graduate students have participated in undergraduate and graduate research projects in power electronics and electric drives sponsored by CPES. UPRM-CPES research program started in year 2 (Fall 1999) with three projects: commissioning of electric drives (modeling of electromechanical systems and robust algorithms for speed and parameter estimation in induction machines), multi-level simulation of electric drives, and cost modeling of power electronic modules [11-13]. Undergraduate research projects in electric drives, motor control systems and chaos applications have also been supported by CPES.

CPES has motivated collaborative experiences between the power engineering area and other ECE areas. The Center has also supported multidisciplinary efforts, especially with the Mechanical Engineering and Industrial Engineering Departments at UPRM [13]. CPES sponsored activities also include presentations and demonstrations using laboratory facilities, and workshops for high school students.

NEW AND REVISED COURSES

The curriculum improvements in power engineering include the revision of course contents and format. This section describes examples of new courses and changes in existing courses that address the need of integrating new technologies and research-oriented activities to the undergraduate curriculum. Improving course content and format benefits both power engineering students and professors.

Power Quality

Power quality problems represent over $16 billion/year in losses for U.S. industry [14], caused in great part by nonlinear loads such as power electronics. Despite having great advantages on the user side, power electronics distort the quality of energy service to industrial, commercial and residential customers by generating harmonics and other undesirable conditions in the system side; and also interfering with other loads on the user side. It is important for students to understand these issues in order to consider them while designing power devices. This was one motivating factor for teaching power quality at UPRM.

Power quality is being offered as a special topics course at UPRM. Most students attending the course have been supported by CPES. The course presents the fundamental concepts of power quality, monitoring and analysis techniques, indices for analysis of disturbances, sources of problems (emphasis on power electronics loads), and mitigating strategies (including power electronic systems as mitigating devices). Students complete review papers that include some implementations, which are compiled and published as a local UPRM CPES report. One of the papers from the class was presented at a major conference on Power Quality in October 2000 [15].

Authorized licensed use limited to: Univ of Texas at El Paso. Downloaded on January 22,2021 at 02:56:01 UTC from IEEE Xplore. Restrictions apply.

Power quality activities at UPRM are providing a link between power systems and power electronics. Collaboration between these two areas has strengthened the power engineering program and energy systems research. A research topic that merges these areas is the generation of power using alternate sources. It is of interest to improve existing models for the power electronics interface between alternate sources and the electric grid, as well as applications of power electronics to power systems (e.g., custom power technologies). Three undergraduate students are presently working in this project.

Revision of the Energy Conversion Lab

A revision of the undergraduate electric machines laboratory was started in 1997 as part of the NSF PECASE award (ECS-9702860) by Dr. Vélez-Reyes. The main purpose of this revision was the introduction of modern computer-based instrumentation, introduction of topics in electric drives and revision of laboratory practices to take advantage of the new facilities. The computers and data acquisition modules enable lab studies in a finer scale, and introduction of time and frequency domain signal-analysis capability. The manual for the laboratory was revised and first used in Fall 1999. Experiments in variable speed drives will be incorporated. There is also an on-going effort to better coordinate the laboratory with the undergraduate electric machines course. The objective is to merge the machines laboratory and the course into a new 4-credit course.

Teaching Electric Power Systems Analysis Using Visually Attractive Tools

Dr. Irizarry-Rivera directed the development of assignments for the Power Systems Analysis course in which the models and methods learned in class are related to "real life" applications [16]. Students must solve the problems using the Internet and a commercially available power system simulator. The homeworks help students visualize the solution of complex electric power system analysis problems. This kind of class work connects the teaching of theoretical principles to actual implementations, increasing student understanding.

Assignments also cover ancillary information normally not needed to solve electric power system analysis problems. Data such as the appearance of the actual apparatus (size, weight, cost, manufacturer of the apparatus), the political and financial context in which the analysis methods described in class are used are equally important. These topics, which are normally referred to but are not included as part of a traditional Power System Analysis course, are covered via assignments. Students write a report, using a two column paper format, thus providing an opportunity to develop their communications skills.

A New Power Engineer

The work described in this paper was primarily motivated by the critical situation faced by power engineering education at many U.S. universities. Lack of interest from students is cited as one of the major reasons for reduced numbers in power engineering courses [2-3]. However, power engineers are a vital piece for the solution of the energy crisis in the U.S., exemplified in California. There might be a shortage of qualified power engineers in the near future [3].

The changes or improvements discussed in previous sections are meant to benefit students. Involving students in the learning process, making them active participants rather than passive observers, transforms the classroom into a true learning environment. The strategies were designed to make the curriculum more attractive to students while instructing them in both classical and current issues affecting power systems worldwide. The goal is to produce a new power engineer, with a solid theoretical background as well as a good practical perspective in solving engineering issues. This new curriculum will enable our graduates to face the energy challenges of today's technological world.

Table III divides strategies in four groups: laboratory experiences, research, new areas of study, contemporary issues and other. Each strategy can be implemented at any institution with a minimum investment. For example, access to a database of papers such as the IEEE on-line service is part of the library system at many institutions. Research can be taken to the classroom by assigning students to search, read and present summaries of journal papers on class topics. Finally, industry participation is very important for this revision. The Power Engineering group has contacted local and national companies to engage in collaborations and discussions about UPRM's power engineering curriculum.

TABLE III
SUMMARY OF STRATEGIES

GROUP	ACTIVITY
Hands-On Experiences	Laboratory practices within courses; machines lab revision
Research	Undergraduate research; Research in the classroom)
New Technologies/Fields of study	Power electronics, CPES Power Quality
Contemporary issues	Energy Systems Seminar Series (ES^3); Special Topics Courses
Other	Industry collaboration, distance learning,, Internet tools

Accreditation

Although accreditation preparation was not the key motivation for this work, the strategies for improving the power engineering curriculum at UPRM have been structured such that results can be used to comply with ABET new accredi-

Authorized licensed use limited to: Univ of Texas at El Paso. Downloaded on January 22,2021 at 02:56:01 UTC from IEEE Xplore. Restrictions apply.

tation criteria. Thus, by implementing strategies to improve the quality of education, the power engineering faculty is also preparing for the EE program accreditation.

ABET criteria include the ability to: conduct experiments, interpret data, design a system, work in teams, communicate effectively and use techniques and skills necessary for engineering practice. Ethical responsibility, impact of engineering solutions, life-long learning and contemporary issues are also included. These criteria are meant as guides from which engineering programs create their own set of expected outcomes for their courses. At the ECE Department, there is an Academic Affairs group coordinating accreditation efforts. The Power Engineering group has been very active within that group. It was the first area within the Department that got involved in the accreditation process by evaluating its curriculum.

The curriculum revision also gave the power group an opportunity to determine areas that needed improvement. For example, the Energy Systems Seminar Series (ES^3) began in the Spring 2001, with presentations by industry, faculty and students on topics directly related to criteria that are not being adequately met by traditional courses.

The group is currently identifying the documentation needed to show how the criteria is met in each course/activity within power engineering. The Group is also revising ABET criteria in order to identify measurable outcomes and objectives for our own program. Another important element in this process is the restructuring of courses to make them outcome-based.

CONCLUSIONS

The Power Engineering group at UPRM has been working for the last two years in activities that improve the quality of education, make students the center of the educational process, and meet most of ABET's criteria. This curriculum revision includes updating courses, integrating laboratories to courses, bringing research to classrooms and enhancing the role of undergraduate research and power electronics within the program. Recent grants by NSF and participation in the Center for Power Electronics Systems provide resources to support this effort. This revision offers alternatives to the crisis in power engineering education created in part by the lack of interest from students. The strategies presented can be adapted at other institutions in their own power engineering courses or through modules that can be integrated to energy-related courses.

ACKNOWLEDGMENTS

We thank Prof. Julio Santiago for his vision and leadership through the years. This work was supported in part by the ERC Program of the National Science Foundation under Award Number EEC-9731677. Support from NSF Awards ECS-9702860 and DUE-0088619 is also acknowledged. UPRM ECE's Industrial Affiliates Program supported undergraduate research projects.

REFERENCES

[1] Greenwald, John "The New Energy Crunch", *TIME*, Jan. 29, 2001, pp. 37-39.

[2] Chowdury, Badrul H. "Power Education at the Crossroads", *IEEE Spectrum*, Oct. 2001, pp. 64-68.

[3] Padhke, A."While We Are Sleeping: A crisis in Power Engineering Education", *IEEE Computer Applications in Power*, July 1999, pp. 10-15.

[4] Bell,T.E. "Proven Skills: The New Yardstick for Schools," *IEEE Spectrum*, vol. 37, no. 9, Sept. 2000, pp. 63-67.

[5] Vélez-Reyes, M.; Pérez-Quiñones, M.; Cruz, J. L., "The Industrial Affiliates Program at the University of Puerto Rico-Mayagüez," *Proceedings of the Twenty-Ninth ASEE/IEEE Frontiers in Education Conference*, November 1999, San Juan, PR, pp. 13c5-13 - 13c5-18.

[6] Boyer, E. *Scholarship Reconsidered: Priorities of the Professoriate*, The Carnegie Foundation, Princeton, New Jersey, 1990.

[7] Irizarry-Rivera, A.; Pérez-Quiñonez, M.; Darken, R. "Using Virtual Worlds to Explore Electric Power Grids and Plants," *Proceedings of the Twenty-Ninth ASEE/IEEE Frontiers in Education Conference*, San Juan, Puerto Rico November 10-13, 1999.

[8] Colón, E.; Contreras, U.; Rodríguez, F.; O'Neill-Carrillo, E. "Development of Tools for the Study of Chaotic Behavior in Power Electronics," *Proceedings of the 7th IEEE Workshop on Computers in Power Electronics*, July 2000, pp. 168-173.

[9] Mohan, N.; Undeland, T.; Robbins, W. *Power Electronics: Converters, Applications and Design*, Wiley, New York, 1995.

[10] Vélez-Reyes, M.; Tranter, E."Center for Power Electronic Systems: Education and Outreach Programs," *NSF Workshop in Multimedia Delivery of Power Electronics Education*, Orlando, Florida, November 12, 2000.

[11] Rivera-Sampayo, R.; Vélez-Reyes, M. "Gray-Box Modeling of Electrical Machines." Submitted to *IEEE Conference on Control Applications*, Mexico, 2001.

[12] Ramos, J.; Vélez-Reyes, M. "Comparison of Parameter Conditioning in Output Error and Equation Error Approaches for Speed and Parameter Estimation in Induction Machines". To appear in *Proceedings of the IEEE International Electric Machines and Drives Conference*, Cambridge, MA, June 2001.

[13] Rullán, A; Méndez, M. "Development of Cost Models for Power Electronics Assemblies." Submitted to *10th Annual Industrial Engineering Research Conference*, Dallas, Texas, May 2001.

[14] Rabinowitz, M. "Power Systems of the Future (Part 2)" *IEEE Power Engineering Review*, vol. 20, no. 3, March 2000, pp. 10-15.

[15] Ramírez-Castro, D.; O'Neill-Carrillo, E.; Santiago, J. "Assessment of Harmonics at a Medical Facility," *Proceedings of the 9th IEEE International Conference on Harmonics and Quality of Power*, October 2000, vol. II, pp. 619-624.

[16] Irizarry-Rivera, A. "Teaching Electric Power System Analysis Using Visually Attractive Tools," *Proceedings of the Twenty-Ninth ASEE/IEEE Frontiers in Education Conference*, San Juan, Puerto Rico November 10-13, 1999.

Authorized licensed use limited to: Univ of Texas at El Paso. Downloaded on January 22,2021 at 02:56:01 UTC from IEEE Xplore. Restrictions apply.