US-China Education Review B 1 (2011) 46-52
Earlier title: US-China Education Review, ISSN 1548-6613

National Electrical Code in Power Engineering Course for Electrical Engineering Curriculum

Rahman M. M. Azizur
Grand Valley State University, Grand Rapids, USA

In order to ensure the safety of their inhabitants and properties, the residential, industrial and business installations require complying with NEC (national electrical code) for electrical systems. Electrical design engineers and technicians rely heavily on these very important design guidelines. However, these design guidelines are not formally taught in engineering curriculum. Recently, a study was performed in the Department of EE (electrical engineering) at GVSU (Grand Valley State University) about the potential inclusion of NEC in our EE curriculum as a part of an existing course on power systems analysis. This paper presents the findings of this study along with the implemented recommendations undertaken after this study. A literature survey was conducted on the EE curriculums of other prominent universities in the state of Michigan and those of our national peer and aspirant peer universities with a special emphasis on power engineering. It was found that power engineering curriculum was shrinking at a steady pace. It was also found that even though NECs were important for electrical design of installations, they were too many and trivial for inclusion in a formal curriculum. It was proposed that we offer a short course on NEC so that students can get familiar with electrical codes and obtain crucial hands-on experience. Completion of this short course was made a mandatory part of qualification for our shop-lab access. Impact of this short course on student learning is presented in this paper.

Keywords: NEC (national electrical code), power engineering curriculum, electrical design

Introduction

In latest decades, the focus of engineering curriculum has been diverted away from power engineering program. At the same time, research on power engineering is consistently enjoying rapid progress. Bose (1998), has reported that the late 20th century is the era of power electronics and information. Truly power engineering and computer have achieved a revolutionary advancement in modern technology in every sphere of our day-to-day life. Sales of high power electronic equipments exceeded $60 billion each year and contributed to another $1 trillion sale in related hardware electronics (Lee & Barbosa, 2001; Salem & Ciezki, 2003). Although these figures reflect the contribution of high power engineering in modern economic trends, the power electronics industries, more generally, the power industries are facing an alarming shortfall (Chowdhury, 2000) in quality workforce with appropriate blend of knowledge in other areas including software and information technology. This is partly due to the lack of student interested in power engineering.

US is going to face a serious energy crisis if appropriate measures are not taken on time. DOE (Department of Energy) statistics (DOE, 2003) show that about 87% of our energy needs come from fossil fuel source

Rahman M. M. Azizur, associate professor, Ph.D., Grand Valley State University.

including foreign petroleum or other sources detrimental to clean environment. To ensure continuity of required energy supply, it is time to look for alternative energy sources. At the same time, to leave a cleaner and safer environment free from pollutions for our future generations, we must look for renewable and cleaner energy sources. Recently, research trends have been showing significant interests on the renewable energy sources like hydrogen fuel-cells, photovoltaic-cells, bio-diesel, wind energy, hydro-electricity, etc.. Almost all of these energy sources have low efficiency and high costs, hence require optimized operation with lower costs. Above all, some of these sources generate low level dc voltage which must be converted to higher level and appropriate frequency to supplement the utility supply. The integration, control strategy, efficient operation and application of these energy sources require expertise in power systems engineering and control electronics.

As a part of significant involvement of the School of Engineering at GVSU (Grand Valley State University) with local industries here in West Michigan, we deal a lot with architectural design companies. Recently, during an industrial advisory board meeting, we were advised that our students should learn about NEC (national electrical code). They emphasized that it is a must for electrical design of domestic and commercial installations. This prompted an investigative study about possible inclusion of NECs in our EE curriculum. This paper presents the results of that study. This paper is outlined as follows: section 2 defines NECs. Contents of currently offered power engineering course at GVSU are given in section 3. Section 4 presents a survey results on the contents of power engineering courses at other prominent universities in the State of Michigan. The results of a survey on the contents of power engineering courses at our comparable and aspirant peer universities in US are given in section 5. Section 6 presents discussions and conclusions of this study.

What is NEC?

NEC is a collection of guidelines for installation developed by NEC committee to ensure the practical safeguarding of persons and property from the hazards arising from use of electricity in the domestic, industrial and commercial end-user facilities. As a part of this study, it was found that these guidelines also known as “articles” are documented in NEC handbook, i.e., NEC handbook is a tabulation of these articles. NEC handbook (Earley, Sheehan, Sargent, Caloggero, & Crousore, 2002) covers: wiring and protection, wiring methods and materials, equipment for general use, special occupancies, special equipments, special conditions, communication systems, etc..

EGR 330 Power Systems Analysis at GVSU

Since 2005, EGR (engineering) 330 Powers Systems Analysis is the only course in power engineering currently offered in the School of Engineering at GVSU. This is a four-credit course offered in 12-week summer semester. Although varies, the latest topics covered in this course are: single-phase and poly-phase systems, balanced and unbalanced three-phase systems, power factor correction, power transmission, DC (direct current) and AC (alternating current) distribution systems, fault analysis which includes symmetrical and asymmetrical fault, and contemporary energy issue-safety, social, and environmental impact. This course includes a three-hour-per-week laboratory activity. Up to this year, no element of NEC was formally taught in this course at GVSU.

NEC and Power Courses at Other Michigan Universities

This section presents a literature survey conducted on the courses offered on power systems at some other prominent universities in the State of Michigan. The purpose of this survey was to figure out any inclusion of NEC as contents of any formal course in those universities.

(1) MSU (Michigan State University): The Department of Electrical and Computer Engineering at MSU offers one course ECE (electrical and computer engineering) 423 Power System Analysis, a three-credit course on regular basis. This course is open to juniors and seniors only. Topics covered in this course are (MSU course catalogue, 2009): synchronous machines, models and measurements of power components, symmetrical components, short-circuit analysis and equipment protection, load flow, voltage and frequency control, operation and planning of power systems.

In addition to this, there are graduate courses on power electronics and machines. However, no element of NEC was formally included or taught in these courses at MSU.

(2) University of Michigan, Dearborn: The Department of Electrical and Computer Engineering at University of Michigan offers the following courses in power engineering (UMD course catalogue, 2009) area:

> ECE 415 Power Electronics—Introduction to power electronic circuit analysis and design; power electronic circuits, power converters, power semiconductors; time domain analysis emphasized; a design project is required; and three lecture hours and one project hour per week.
>
> ECE 446 Electromechanical Conversion—Electric and magnetic storage and transfer: inductors, capacitors and transformers; electromechanical energy conversion: variable reluctance devices, AC and DC machines; analysis and performance of AC and DC machines; symmetric components; transient and dynamic analysis; linearization and computer analysis; and three lecture hours and one three-hour laboratory period.

Even though there is no formal course on Power Systems Analysis, there are several courses on special topics that include circuits, power systems topics, electrical vehicle I and II, etc.. However, no element of NEC was formally included or taught in these courses at the University of Michigan, Dearborn.

(3) Western Michigan University: The Department of Electrical and Computer Engineering at Western Michigan University offers one course in power systems analysis ECE 4300 Electrical Power Systems. Topics covered in this course (WMich course catalogue, 2009) include: three-phase circuits and per-unit notation; distributed RLC for conductors and cables; transmission lines, network analysis, symmetrical system faults, and introduction to symmetrical components; and credit: three hours (three hours lecture).

In addition to this, two courses on electrical machinery and power electronics are offered. However, no element of NEC was formally included or taught in these courses at Western Michigan University.

(4) MTU (Michigan Technological University): The EE program at MTU offers following four courses on power systems analysis (MTU course catalogue, 2009):

> EE 4221 Power System Analysis 1: Topics include complex power flow in circuits and the effect of real and reactive power flow on a system; transformer and load representations in power systems; power transmission line parameters and steady-state operation of transmission lines; the per unit system; development of bus admittance matrix; and power flow.
>
> EE 4222 Power System Analysis 2: Topics covered include symmetrical components; symmetrical faults; unbalanced faults; generating bus impedance matrix and using it in fault studies; power system protection; power system operation; and power system stability.
>
> EE 4223 Power System Protection: Real-time monitoring and protection of modern power systems, secure and reliable operation of radial and grid systems; Protection of transmission line lines, buses, generators, motors, transformers and other equipment against disturbances.

> EE 4225 Distribution Engineering: Modeling and analysis of electrical distribution systems; load characteristics, load modeling, unbalanced three-phase overhead and underground line models, distribution transformers, and Analysis of over current protection, voltage drop, and power quality.

In addition to these courses, there are two more courses on energy systems and machine. However, even though it is a technological university, no element of NEC was formally included or taught in these courses at MTU.

As presented in this section, none of the courses offered in above mentioned universities in the State of Michigan teaches or includes NEC in their curriculums. It should be mentioned here that most of the above universities have more than one course and faculty in power engineering. On the top of that EGR 330 at GVSU covers more topics than any of the above-mentioned courses alone.

NEC and Power Courses at Peer Universities

This section presents a literature survey on power system courses offered at our comparable and aspirant peer universities at national level (Ray, 2007). The purpose of this survey was to figure out any possible inclusion of NEC as contents of any formal course in these peer universities.

(1) Bradley University (comparable peer): Department of EE at Bradley University offers on course in power systems engineering (Bradely University course catalogue, 2009):

The topics of EE 575 Power Systems I (three hours) include: analysis of electric power systems: fault studies; load flow; economic loading; stability; relaying; high voltage DC transmission; lightning and switching transients; and prerequisite: senior or graduate standing in EE.

In addition to this course, there is a graduate cum undergraduate course on power electronics EE 409/EE 691. However, no element of NEC was formally included or taught in these courses at Bradley University.

(2) Mercer University (comparable peer): Department of ECE (Electrical and Computer Engineering) at Mercer University offers the course on power systems (Mercer course catalogue, 2009) as follows: ECE 471/571 Power Systems Fundamentals (3-0-3): Prerequisites: C or better in ECE 202, C or better in EGR 245. Topics include: basic power system analytical concepts, three-phase systems, phasors, impedances, steady-state network analysis, normalization, transmission lines, transformers, synchronous machines and power flow.

In addition to this course, there is a graduate/undergraduate course on power electronics ECE 411/ECE 511. However, no element of NEC was formally included or taught in these courses at Mercer University.

(3) CSU (California State University), Northridge (comparable peer): The Department of Electrical and Computer Engineering at CSU, Northridge, offers courses on power systems (Cal State course catalogue, 2009) as follows:

> ECE 411 Electrical Power Systems (3.0): review of basic principles such as complex power, nuclear, hydroelectric and fossil power plant generation; transmission line parameters, flux linkages, impedance, line capacitance; design of transmission lines, V-I (voltage-current) relationships, wave analysis, models and power handling capabilities; transformer and generator analysis at the power systems level; per unit system analysis; two port analysis and design of power transmission lines; and use of software such as: Matlab, C program, visual basic, and excel for the simulation, design and homework.

There are three graduate courses on power systems: ECE 610 Fault Analysis in Power Systems, ECE 611 Power Distribution Systems and ECE 612 Selected Topics in Power Systems. In addition to these, CSU-Northridge offers ECE 410 electrical machines and energy conversion and ECE 412 power electronics as undergraduate courses. However, no element of NEC was formally included or taught in these courses at CSU at Northridge.

(4) Rowan University (aspirant peer): Rowan University is one of our aspirant peer universities in US. The Department of Electrical and Computer Engineering at Rowan University offers two courses on power systems (Rowan University course catalogue, 2008) as outlined below. However, no element of NEC was formally included or taught in these courses at Rowan University.

> ECE 0909.408.01/0909-504-02 power system engineering: This is a foundational course in the engineering, design, construction, operation and key theoretical principles of modern electric power systems (generation, transmission, substations, distribution and end-use). The course includes such topics as: history and key inventions in the development of the electric power industry, mechanical and electromagnetic fundamentals, three phase circuits, transformers, AC machinery fundamentals, synchronous machines, induction motors, DC machines, transmission lines, introduction to power flow, system reliability-relay and control engineering, power generation fuels (fossil, nuclear, solar, geothermal and tidal), advanced generation technologies, PV (photo-voltaic) system design, fuel cells, piezo/thermoelectrics), utility industry organization and deregulation, remote/stand-alone electric power systems, end-use devices, systems and efficiency, sustainable designs for electric power.
>
> ECE 09.402.02/ECE 09.504.02 Advanced Power Systems: This is a foundational course in the engineering, design, construction, operation and key theoretical principles of Advanced Electric Power Systems (modern generation technologies, fuel cells, photovoltaic systems, wind energy technologies). The course includes such topics as: basic electric & magnetic circuits, electric fundamentals, infrastructure and today’s industry, distributed generation and resources, fuel cell technologies, engineering economics of power technologies, wind turbine generation technology, the solar resource, PV fundamentals, system design.

(5) California Polytechnic State University, Cal Poly (aspirant peer): This university is one of our aspirant peer universities in US. The Department of Electrical and Computer Engineering at Cal Poly offers following courses (Cal Poly course catalogue, 2007) on power systems:

> EE 406 Power Systems Analysis I: introduction to electric power systems; representation of power systems, and its components including transmission lines, synchronous machines, transformers and loads; one line diagrams and per unit calculations, symmetrical faults; load flow analysis; four lectures; prerequisite: EE 335 with a C- grade or better, EE 255 & 295.
>
> EE 407 Power Systems Analysis II: symmetrical components, unbalanced faults, power system stability, system protection, relays and relay systems, power system instrumentation and measurement techniques, economic operation; four lectures; prerequisite: EE 406.
>
> EE 518 Power System: protection unsymmetrical faults; protection fundamentals; instrument transformers; power system grounding; generator protection, transformer protection, busbar protection, line and motor protection; four seminars; prerequisite: EE 407 or equivalent, and graduate standing or consent of instructor.
>
> EE 519 Advanced Analysis of Power Systems: advanced power system stability analysis, numerical methods in power system analysis; four seminars, prerequisite: EE 406 or equivalent, and graduate standing or consent of instructor.

In addition, there are number of courses offered as EE 255 Energy Conversion and Electromagnetics, EE 410 Power Electronics I and EE 411 Power Electronics II. However, no element of NEC was formally included or taught in these courses at Cal poly.

As presented in this section, none of the courses offered in our above mentioned comparable peer and aspirant peer universities in the United States of America formally teaches or includes NEC in their curriculums. However, some of the courses cover some important topics, such as grounding systems, fault and line protection, motor control, etc.. They are covered, including lab work, to enhance hands-on experience of graduating engineers. It should be mentioned here that most of the above universities have more than one course in power engineering.

Recommendations and Implementations

In compliance with the curriculum change procedure, after this study was performed, the author had a series of meetings with EE faculty members and other staff of the School of Engineering. Based on the discussions of these meetings, it was concluded that even though NEC are important, they are too many and trivial to be included in a formal curriculum. Once our graduates are familiar with the NEC handbook, they should be able to use it professionally and effectively. Although we should include materials for course contents to enhance practical experience, we must not cross the fine line between an engineer and a technician. To strengthen hands-on experience, it was suggested and finally decided that we would offer a week-long short course on NEC instructed by a certified electrician. The online of this short course was proposed to EE faculty and finalized as follows:

(1) Course title: Electrical Proficiency Qualifications Course;

(2) Description: The purpose of this course is to ensure that students have the necessary skills for correct and safe work with electrical circuits. The students will learn laboratory safety and procedures, NEC usage, types of insulation, wire size for wiring, etc.. They will also learn how to use solder/desoldering processes, techniques and equipment. They will also complete a soldering and wiring project;

(3) Co-requisite: Upper-level standing in the School of Engineering;

(4) Textbook: NEC 2008, NFPA 70 (Not required); E-book on Webpage: http://www.gvsu.edu/library/. Search for “NECs”, check out the book from the library or reference the e-book on line;

(5) Goals: The primary purpose of this course is to fill in the gap between the theory, ideas and projects assigned to students in all EGR courses with hands-on projects. After completing this course: (a) Students will be informed of the safety hazards in EE laboratories and how to safely use the relevant equipment; (b) Students will learn about 1-phase and 3-phase 120/220VAC circuits and how to choose and wire plugs and receptacles appropriate for a circuit’s voltage and current ratings; (c) Students will learn proper grounding procedures and proper ESD (electro-static discharge) management; (d) Students will learn how to apply the NEC in the construction and wiring of the electric circuits. NEC coverage will include sections 200, 240, 250, 280, 404, 406, 408, 411, 440, 450, 670, 685, 701, 720 and 800; (e) Students will learn soldering safety, equipment used in soldering, types of solder, standard through-hole pin soldering and desoldering using both solder sucker pump and solder wick. Students will also learn surface-mount soldering/desoldering with fine tips, fine solder and solder wick and hot air desoldering, use of flux and flux remover, and control of temperature as a function of the soldering/desoldering tasks; (f) Students will complete a simple soldering project; and (g) Students will complete a simple 120/220 V wiring project.

This short course was offered twice every year since the winter of 2008 and later changed to once a year. Successful completion of this short course has been made a mandatory part of qualifications for some shops and lab accesses. As a result, our students enter junior and senior years are completely ready to deal with electrical and electronic circuit designs.

Conclusions

Importance and potential for inclusion of NECs as a part of EE curriculum are investigated. Prominent universities in the State of Michigan and our comparable and aspirant national peers are used as a reference for this study. As explained in section 4 and section 5, although all of these universities have more than one course on power system analysis, none of them formally teaches or includes NEC as a part of their curriculums while interests in power engineering are shrinking gradually. On the other hand, most of these universities have more than one course but a few faculty members specialized in power engineering. After reviewing the NEC handbook it has been noticed that while these codes are important design guidelines, they were too many and trivial to be included in a formal EE curriculum. It was concluded that while accommodating important and emerging course materials for EE curriculum to enhance hands-on experience, we must not cross the boundary line between an engineer and a technician regarding practical experience. As they progress through our program, our graduating engineers get enough background and hands-on experience to handle most of the NEC issues at workplace. Hence, there is no need to formally include NEC in a course work. However, some of the topics from NEC including detailed grounding circuits and wirings, current rating calculation for loads like range and oven, etc., could still be covered in EGR 330 Power Systems Analysis. Some of the topics on motor control may be covered in EGR 430 electro-mechanics as special topics. This remains to be investigated in future. It was recommended that we should offer a short course or workshop twice every year on electrical design and drafting by a certified electrician. Since the winter of 2008, a week-long short course is being offered to students with upper level standing. Even though it was planned to offer short course twice every year, plan was changed to once a year offering due to the limitation of resources. Also, the completion of this short course has been made a requirement for laboratory and shop access qualification. It has been found that this short course was very beneficial to our students' lab, course project and senior design project work as they progress through our program.

References

Bose, B. K. (1998). Advances in power electronics—Its impact on the environment. Proceedings of *IEEE International Symposium on Industrial Electronics* (Vol. 1, pp. 28-30).

Bradely University course catalogue. (2009). Retrieved from http://cegt201.bradley.edu/coursework/bsee.shtml

Cal State course catalogue. (2009). Retrieved from http://www.csun.edu/ece/courses.htm

Cal Poly course catalogue. (2007). Retrieved from http://www.calpoly.edu/%7Eacadprog/2007depts/cengr/ee_dept/eecrs2007.pdf

Chowdhury, B. H. (2000). Power education at the crossroads. *IEEE Spectrum* (pp. 64-68), October 2000.

Earley, M. W., Sheehan, J. V., Sargent, J. S., Caloggero, J. M., & Crousore, T. M. (2002). *NEC 2002 national electrical code handbook.* GVSU: Steelcase library.

Energy review statistic. (2003). Department of Energy. Retrieved from www.doe.gov

Lee, F. C., & Barbosa, P. (2001). The state of the art power electronics technologies and future trends. Records of *IEEE Transmission and Distribution Conference and Exposition* (Vol. 2, pp. 1188-1193).

Mercer course catalogue. (2009). Retrieved from http://www.mercer.edu/engineering/undergraduate_pgms/ece/courses/index.htm

MSU course catalogue. (2009). Retrieved from http://www.egr.msu.edu/ece/students/courses/undergraduate_index.php

MTU course catalogue. (2009). Retrieved from http://www.banweb.mtu.edu/pls/owa/stu_ctg_utils.p_online_all_courses_ug#EE

Ray, J. L. (2007). *Workload planning update.* Grand Valley State University.

Rowan University course catalogue. (2008). Retrieved from http://www.rowan.edu/catalogs/pdf/UG2007-2008.pdf

Salem, T. E., & Ciezki, J. G. (2003). An assessment of power engineering education. *ASEE Annual Conference and Exposition records* (Session 2132).

UMD course catalogue. (2009). Retrieved from http://www.engin.umd.umich.edu/ECE/newECE/programs/programs.htm

WMich course catalogue. (2009). Retrieved from http://www.wmich.edu/ece/academics/courses.html