National Electrical Code – a Eequirement for Electrical Engineering Curriculum

M.M. A Rahman, Senior Member IEEE, Member ASEE
301 W Fulton Street, 136 Kennedy
Grand Valley State University
Grand Rapids, MI 49504
rahmana@gvsu.edu

Abstract - **National Electrical Code (NEC) provides important guidelines to design electrical systems for residential, industrial, and business installations without compromising safety of persons and properties. This is a very important tool for electrical design engineers and technicians. Recently, a study was performed in the department of Electrical Engineering at Grand Valley State University about potential inclusion of NEC in our Electrical Engineering 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 Electrical Engineering curriculums of other prominent universities in the state of Michigan and those of our national peer and aspirant peer universities. It was found that even though electrical codes are important for electrical design of installations they are too many and too trivial for 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 shop-lab access. Impact of this short course on student learning is presented in this paper.**

Index Terms – National electrical codes, Electrical Engineering curriculum, Electrical design.

1. INTRODUCTION

As a part of significant involvement of the School of Engineering at 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 learn about national electrical codes. They emphasized that it is a must for electrical design of domestic and commercial installations. This prompted an investigative study about possible inclusion of national electrical code in our Electrical Engineering curriculum. This paper presents the results of that study. This paper is outlined as follows: Section 2 defines national electrical codes. 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. A survey results on the contents of power engineering courses at our comparable and aspirant peer universities in USA are given in Section 5. Section 6 presents discussions and conclusions of this study.

2. WHAT IS NEC?

NEC is a collection of *guidelines for installation* developed by National Electrical Code 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. These guidelines also known as *articles* are documented in NEC Handbook i.e. NEC Handbook is a tabulation of these articles. NEC Handbook [1] covers: *wiring and protection, wiring methods and materials, equipment for general use, special occupancies, special equipment, special conditions, communication systems, etc*.

3. EGR 330 POWER SYSTEMS ANALYSIS AT GVSU

EGR 330 Powers Systems Analysis is the only course in power engineering currently offered in the School of Engineering at Grand Valley State University. This is a 4 credits 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 3-phase systems, Power factor correction, Power transmission, DC and AC distribution systems, Fault Analysis: symmetrical and asymmetrical fault, and contemporary energy issues - safety, social, and environmental impact. This course includes a 3 hours per week laboratory activities.* Up to this year no element of national electrical code was taught in this course at GVSU.

4. 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. Purpose of this survey

was to figure out any inclusion of national electrical code as contents of any formal course in those universities.

a) Michigan State University: The department of Electrical and Computer Engineering at Michigan State University offers one course ECE 423 Power System Analysis, a 3 credit course on regular basis. This course is open to juniors and seniors only. Topics covered in this course are [2]:
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 national electrical code was formally included or taught in these courses at MSU.

b) University of Michigan, Dearborn: The department of Electrical and Computer Engineering at University of Michigan offers following courses in power engineering [3] 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. 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. 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 national electrical codes was formally included or taught in these courses at the University of Michigan, Dearborn.

c) 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 [4] 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. Credit: 3 hours (3 hours lecture)*

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

d) Michigan Technological University: The Electrical Engineering program at Michigan Tech offers following four (4) courses on power systems analysis [5]:

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; 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; 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, and distribution transformers. Analysis of over current protection, voltage drop, and power quality.*

In addition to these courses, there are 2 more courses on energy systems and machine. However, even though it is a technological university no element of national electrical codes 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 national electric codes in their curriculum. It should be mentioned here that most of the above universities has more than one (1) 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.

5. NEC AND POWER COURSES AT PEER UNIVERSITIES

This section describes a literature survey on power system courses offered at our comparable and aspirant peer universities [6] at national level. Purpose of this survey was to figure out any possible inclusion of national electrical codes as contents of any formal course in these peer universities.

a) Bradley University (comparable peer)**:** Department of Electrical Engineering at Bradley University offers on course in power systems engineering [7]:

EE 575 Power Systems I (3 hrs). Topics include: *Analysis of electric power systems: fault studies; load flow; economic loading; stability; relaying; high voltage DC transmission; lightning and switching transients.* 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 national electrical codes was formally included or taught in these courses at Bradley University.

b) Mercer University (comparable peer): Department of Electrical and Computer Engineering at Mercer University offers on course on power systems [8] 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, power flow.*

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

c) California State University - Northridge (comparable peer): The Department of Electrical and Computer Engineering at California State University – Northridge offers courses on power systems [9] as follows:

ECE 411 Electrical Power Systems (3.0): Course Description: *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 relationships, wave analysis, models and power handling capabilities. Transformer and generator analysis at the power systems level. Per unit system analysis. 2 port analysis and design of power transmission lines.* Use of software such as: Matlab, C, Visual Basic and Excel for the simulation, design and homework.

There are three (3) 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 national electrical codes was formally included or taught in these courses at CSU at Northridge.

d) Rowan University (aspirant peer): Rowan University is one of our aspirant peer universities in USA. The Department of Electrical and Computer Engineering at Rowan University offers two courses on power systems [10] as outline below. However, no element of national electrical codes was formally included or taught in these courses at Rowan University.

ECE 0909.408.01/ECE 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 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: Course Description: *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*.

e) California Polytechnic State University -Cal Poly (aspirant peer): California Polytechnic State University -Cal Poly is one of our aspirant peer universities in USA. The department of electrical and computer engineering at Cal Poly offers following courses [11] on power systems:

EE 406 Power Systems Analysis I (4) *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.* 4 lectures. Prerequisite: EE 335 with a C-grade or better, EE 255 & 295.

EE 407 Power Systems Analysis II (4) *Symmetrical components, unbalanced faults, power system stability, system protection, relays and relay systems, power system instrumentation and measurement techniques, economic operation.* 4 lectures. Prerequisite: EE 406.

EE 518 Power System Protection (4) *Unsymmetrical faults. Protection fundamentals. Instrument transformers. Power system grounding. Generator protection, transformer protection, busbar protection, line and motor protection.* 4 seminars. Prerequisite: EE 407 or equivalent, and graduate standing or consent of instructor.

EE 519 Advanced Analysis of Power Systems (4) *Advanced power system stability analysis, numerical methods in power system analysis.* 4 seminars. Prerequisite: EE 406 or equivalent, and graduate standing or consent of instructor.

In addition to these 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 national electrical codes 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 national electrical codes in their curriculum. However, some of the courses cover some important topics such as grounding systems, fault and line protection, motor control, etc. These 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.

6. RECOMMENDATIONS AND IMPLEMENTATIONS

After this study was performed, author had a series of meetings with Electrical Engineering faculty members and other staff of the School of Engineering. Based on the discussions of these meetings it was concluded that even though national electrical codes are important they are too many and too 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 that we offer a week long short course on NEC instructed by a certified electrician. This course contents was proposed to EE faculty and finalized as follows:

Course Title: Electrical Proficiency Qualifications Course

Description: The purpose of this course is to ensure that students have the necessary skills for correctly and safely working with electrical circuits. The student will learn Laboratory Safety & Procedures, National Electrical Code Usage, Types of Insulation, Wire Size for wiring, etc. The student will also learn how to use Solder/Desoldering processes, techniques and equipment. The Student will also complete a soldering and wiring project.

Co-requisite: Upper-level standing in the School of Engineering

Textbook: NEC 2008, NFPA 70 (Not required); E-book on webpage: http://www.gvsu.edu/library/. Search for "National Electrical Codes", Check out the book from the Library or reference the E-book on line.

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: (1) Students will be informed of the safety hazards in EE laboratories and how to safely use the relevant equipment, (2) 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, (3) Students will learn proper grounding procedures and proper ESD management, (4) Students will learn how to apply the NEC (National Electrical Code) in the construction and wiring of electric circuits. NEC coverage will include sections 200, 240, 250, 280, 404, 406, 408, 411, 440, 450, 670, 685, 701, 720, and 800. (5) 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. (6) Students will complete a simple soldering project, (7) Students will complete a simple 120/220VAC wiring project.

This short course is being offered twice every year since winter 2008. Successful completion of this short course has been made a mandatory part of qualifications for some shop and lab access. As a result our students enter junior and senior years being completely ready to deal will electrical and electronic circuit design.

7. CONCLUSIONS

Potential of national electrical codes as a part of electrical engineering curriculum is investigated. In-state universities 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 universities have more than one course on power system analysis, none of them formally teaches or includes NEC as a part of their curriculum. On the other hand most of these universities have more than one course and faculty specialized in power engineering. After reviewing the NEC handbook it has been noticed that while these codes are important design guideline they are too many and too trivial to be included in a formal Electrical Engineering curriculum. It was concluded that while accommodating important materials for electrical

engineering curriculum to enhance hands-on experience we must not cross the boundary line between an engineer and a technician regarding practical experience. Hence, there is no need to formally include NEC in a course work. Our graduating engineers get enough background and hands-on experience to handle most of the NEC issues at workplace. However, some of the topics including detailed grounding circuit and wiring, current rating calculation for loads like range and oven, etc. can 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 offer a short course or workshop twice every year on electrical design and drafting by a certified electrician. Since winter 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. It has been found that this short course is very beneficial to our students' lab and project work as they progress through our program.

ACKNOWLEDGEMENT

Author would like to thank Dr. Andrew Sterian for many valuable discussions during the course of this study. Author would also thank Mr. Ron Grew, laboratory supervisor for working hard to develop and instruct a short course "Electrical Proficency Course" that enhances a background on NEC.

REFERENCES

1. M.W. Earley, J.V. Sheehan, J.S. Sargent, J.M. Caloggero and T.M. Crousore, "NEC 2002 National Electrical Code Handbook", TK 3275.N4, Steelcase library, GVSU
2. http://www.egr.msu.edu/ece/students/courses/undergraduate_index.php
3. http://www.engin.umd.umich.edu/ECE/newECE/programs/programs.htm
4. http://www.wmich.edu/ece/academics/courses.html
5. https://www.banweb.mtu.edu/pls/owa/stu_ctg_utils.p_online_all_courses_ug#EE
6. J.L Ray, "Workload Planning Update", May 2007
7. http://cegt201.bradley.edu/coursework/bsee.shtml
8. http://www.mercer.edu/engineering/undergraduate_pgms/ece/courses/index.htm
9. http://www.csun.edu/ece/courses.htm
10. http://www.rowan.edu/catalogs/pdf/UG2007-2008.pdf
11. http://www.calpoly.edu/%7Eacadprog/2007depts/cengr/ee_dept/eecrs2007.pdf

AUTHOR INFORMATION

M.M. Azizur Rahman is an associate professor of electrical engineering at Grand Valley State University, Grand Rapids, MI, USA.

Feedback suggested electrical engineers, suppliers and contractors now realize it doesn't matter where a GFCI is installed and that we need not identify different locations. CMP 2 also recognized that a hazard doesnâ€™t change when a circuit is greater than 20 amps. Whether an installation is 15 to 20 amps or 60 amps, circuit risks still exist and protection is warranted.Â 2020 code changes will be substantial in that the code-making panel looks to soon modify tried-and-true requirementsâ€”some of which have existed for decades. Of course, there are many details to consider both now and in the future. As part of this continuing series, my Eaton colleagues and I will dig deeper into each of the topics Iâ€™ve listed and offer opinions on where the NEC may take safety tomorrow. This Code covers the installation and removal of electrical conductors, equipment, and racewaysÂ Adopted in all 50 states, NFPA 70, National Electrical Code (NEC) is the benchmark for safe electrical design, installation, and inspection to protect people and property from electrical hazards. NOTE: Due to the COVID-19 pandemic and NFPAâ€™s efforts to safeguard our attendees at NFPA meetings, the NECÂ® First Draft meetings are being held as a series of telephone/web conferences during the months of November 2020, December 2020 and January 2021. Meeting notices and schedules are posted on the Next Edition tab. NFPA extends sincere apologies for any inconvenience this may cause. Thank you for yo