Establishment of a Nuclear Engineering Minor Program

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Abstract

In Fall 2009, the College of Engineering at UT Arlington began to offer a minor in nuclear engineering for its students. The rationale for the establishment of the program is explained, as well as the nature of the program and the status of the program after three full years.

Introduction

The impact of the Fukushima nuclear accident on the future of nuclear industry has not been experienced uniformly worldwide. Different countries have had differing reactions to the accident, and generally speaking the impact can be categorized in four ways. Some European countries like Germany, Italy and Switzerland had the reactionary decision to scale down or stop their nuclear energy programs, but no one knows whether these countries will rethink their nuclear energy policy when faced with economic realities and carbon emission restrictions. At the same time, some countries like China and India are continuing their nuclear program with determination. China has 16 existing nuclear power plants and is planning to add 197 new plants of which 26 are already under construction [1]. India has 20 nuclear power plants and aims to add 64 reactors that will supply 25% of their electricity demand by 2050 [1,2]. A third category consists of countries that plan to jump start their nuclear programs; countries like Saudi Arabia have high ambitions to build 16 nuclear reactors over the next 20 years [3]. Finally the United States with 104 operating nuclear power plants produces 30% of the worldwide electric generation by nuclear energy. Although this is the largest in the world, there have been no new reactors built in USA and the future growth looks sluggish with 4-6 new nuclear power plants planned by 2020.

One can conclude that, in spite of the Fukushima disaster, a number of countries are proceeding to develop their domestic nuclear energy programs. However, these countries are facing a severe shortage of qualified, available personnel. The problem is compounded by the fact that many

experienced nuclear workers and professionals are approaching their retirement age;-soon there will be a shortage of nuclear engineers able to fill the available positions. This workforce scarcity is already existing within the USA and worldwide.

Hence, in response to the existing and anticipated future national and regional need for nuclear engineers, UT Arlington's College of Engineering began to offer a minor in Nuclear Engineering (NE) in fall of 2009. The decision to begin this offering was strongly influenced by the following observations:

- UT Arlington is in a close proximity to the Comanche Peak Nuclear Power Plant and the Region IV Office of the US Nuclear Regulatory Commission (NRC). In addition there are a number of companies in the area which provide services and consultation to these entities.
- Comanche Peak has indicated the intent to build two more new nuclear power plants in the state of Texas.
- The national and regional need for engineers with training in nuclear engineering is currently not being met by any university in the Dallas / Fort Worth area.
- Several faculty members at UT Arlington hold PhD degrees in nuclear and related engineering fields.
- Several members of the College's Advisory Board are involved in power generation industry and have voiced unequivocal support for this program.
- The faculty and administration of the College of Engineering have been very supportive, providing both moral and financial support to initiate the minor.

The nuclear industry, particularly nuclear power generating companies, hires engineers from all disciplines. The majority of these hires come from mechanical or electrical engineering. These engineers are involved with design, construction, operations, maintenance, quality assurance, information technology and radiation protection / monitoring. The NE minor is available to UT Arlington students pursuing a major in either engineering or physics. Our minor in NE is intended to provide additional breadth to our existing engineering curriculum. Students planning to seek an advanced degree in engineering can also benefit from a minor in nuclear engineering. Over the last three years we also have had students that pursue the nuclear minor simply because of their personal interest.

Requirements for Minor in Nuclear Engineering

In general, at a higher education institution, courses towards minor degrees are considered to be additional courses in a specific area of study. In the College of Engineering at UT Arlington, there are six different engineering minors which are adjunct to the major engineering degrees. The undergraduate minor in Nuclear Engineering (NE) program was developed mainly for mechanical & aerospace (MAE) and electrical engineering (EE) students, but it is open to all undergraduate engineering majors and science students who meet the math and physics requirements.

The NE minor requires core courses in nuclear engineering and elective courses in thermal sciences, material science and electrical courses in electromechanical energy conversion and control. These optional courses already exist in the course catalog within the College of Engineering.

The minor program requires at least six 3000 and 4000 level courses, including three core courses (Introduction to Nuclear Engineering, Nuclear Reactor Theory/Analysis and Nuclear Reactor Thermal Hydraulics) and three 3000 and 4000 level elective courses, chosen from a set of 8 courses currently available. The following three core courses were developed for the Nuclear Engineering minor:

NE 3301. Introduction to Nuclear Engineering (3 credit hours, 3 lecture + 2 hours lab)
Catalog Course Description
Catalog description: Fundamentals of radiation, radiation decay, binding energy, types of interactions, shielding, and radioisotopes, fission cross section, fission in a reactor, controlling fission chains, basic reactor model, reactor theory, reactor generations I, II, III, IV, review heat transfer terms, reactor coolant, LOCA, reactor accidents, safety, emergency planning zone, nuclear fuel and fuel cycle, waste storage, decontamination and decommissioning, fusion power, regulating nuclear reactors, nuclear power economics and environment;
Prerequisite: Math 3319 (differential equations / linear algebra) or MAE 3360, Phys 1444 (general technical physics II)

Course Learning Goals/ Objectives
The course objectives for NE 3301 Introduction to Nuclear Engineering are to provide the following:

- Introduction to the fundamental principles of nuclear engineering. These topics include atomic and nuclear physics, fission and fusion, isotopes and radioactivity, nuclear reactions, chart of nuclides, radiations; detection and interaction with matter.
- Introduction to criticality and reactor kinetics, reactor licensing, safety, economic and environment impact.
- In addition to light water reactors, introduction to the CANDU, Gas Cooled Reactors, Liquid Metal Fast Breeder and fusion reactors design.
- Discussion of lessons learned from the Three Mile Island and Chenobyl accidents.
- Discussion of Generation II (current) and Generation III, IV (future nuclear) nuclear power plants.
- Discussion of fuel loading, coolant, loss of coolant, severe accidents, reprocessing, spent fuel management and storage.
- Use of radiation detection instruments, detection limits, and uncertainty analysis of measurements.
- Visit to a nuclear power plant
- Interaction with invited guest speakers from the nuclear industry

NE 4302. Nuclear Reactor Theory/Analysis (3 credit hours, lecture)
Catalog Course Description
The neutronics behavior of fission reactors, primarily from a theoretical, one-speed perspective. Criticality, fission product poisoning, reactivity control, reactor stability and introductory concepts in fuel management, followed by slowing down and one-speed diffusion theory. Multi-group diffusion theory, finite-difference and nodal methods, core heterogeneous effects, pin power reconstruction, thermal neutron spectra, fine group whole spectrum calculations and coarse group constant generation.
Prerequisite: Introduction to Nuclear Engineering

Course Learning Goals/ Objectives
The course objectives for NE 4302 Nuclear Reactor Theory/Analysis are to provide the following:

- Introduction to the fundamental principles governing nuclear fission chain reactions in a manner that renders the transition to practical nuclear reactor design methods.
- Demonstration of the close relationship between the nuclear analysis of the reactor core and those nonnuclear aspects of the core analysis, such as nuclear materials and thermal-hydraulics.
- Introduction to a number of more practical problems in the nuclear reactor design for various types of power reactors.

NE 4303. Nuclear Reactor Thermalhydraulics (3 credit hours, lecture)
Catalog Course Description
This course will introduce the students to the processes of energy (heat) generation in nuclear reactor, the transport of that energy by the reactor coolant to the power cycle, and the limitations imposed by the transport mechanism on the design of nuclear reactor cores. Fundamental calculations associated with these processes will be explained, examples set and their results will be discussed. An effort would be made to familiarize the students with a thermal hydraulic software code**.**
Prerequisite: NE 3301 (Introduction to Nuclear Engineering), MAE 3314 (Heat Transfer) or MAE 3309 (Thermal Engineering)

Course Learning Goals/ Objectives
The course objectives for NE 4303 Nuclear Reactor Thermalhydraulics are to provide the following:

- An understanding of the heat transfer and fluid flow mechanisms in reactor systems. These topics include conduction, convection and radiation and how heat is generated in the fuel rod and transferred to the coolant. Heat generated in the reactor shield and other structural material due to gamma-ray interaction is also discussed.
- An appreciation of the limits on safe power removal from reactor cores. The topics include thermal safety limits like critical heat flux, departure from nucleate boiling and hot channel and hot-spot factors.
- The ability to perform basic calculations of thermal hydraulic quantities in core channels. This involves both computer based and traditional calculations for fuel rod, sub-channel and reactor core analysis.

All courses for the minor require a grade of C or higher. Figure 1 shows the coursework requirement and sequence for the minor in NE at UT Arlington.

MAE students are required to take three technical electives as their curriculum requirement and they can take the three NE core courses to satisfy the requirements for the NE minor degree. EE students could use NE 3301 for their engineering elective but two additional courses are required beyond their EE curriculum requirement. Physics majors and other engineering disciplines will likely have to take more than two additional courses to complete their degree plans.

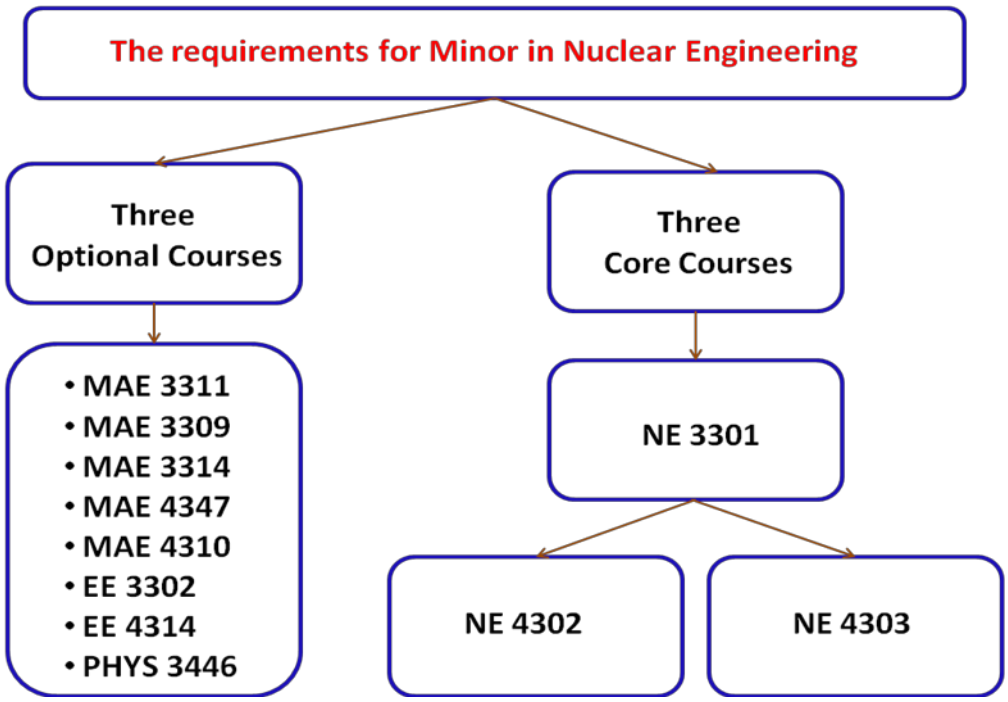

Fig 1. Coursework Requirement and Sequence for Minor in NE at UT Arlington

Since Fall 2009, there has been a strong interest in the NE minor among students. Following approval of the NE minor by the university in the Spring 2009, the first course in the minor, Introduction to Nuclear Engineering, was first offered in Fall 2009. The course capacity was initially capped at 20, raised to 30 and was actually taught with 39 students. Figure 2 shows the statistics for the Enrollment in NE 3301 course. High enrollment in the first year shows the need for the program and excitement of the students. The enrollment for last three years shows a steady increase.

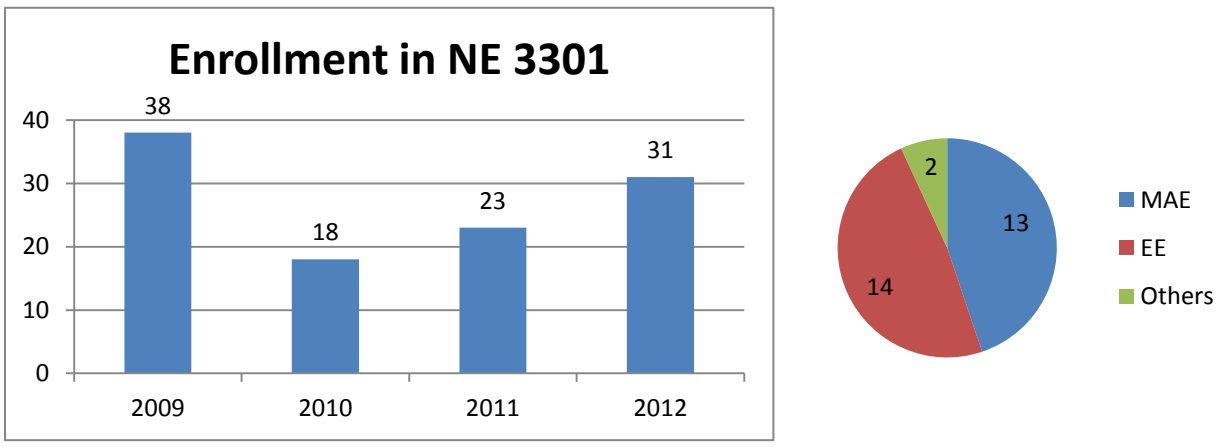

Fig 2. Enrollment in the first core course, NE 3301, during 2009–2012 and the enrollment by major (showing the average number of majors each year, over four years)

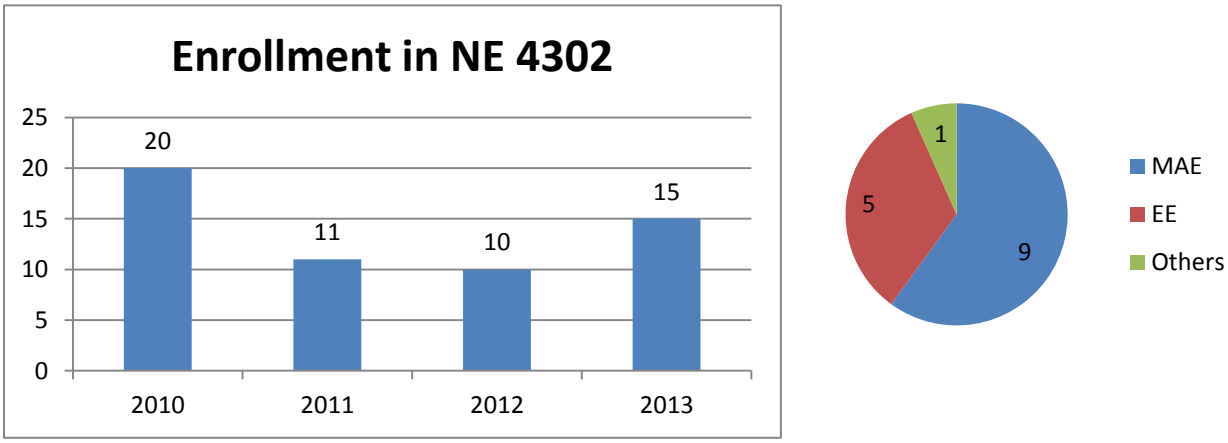

Fig 3. Enrollment in the second core course, NE 4302, during 2009–2012 and the enrollment by major (showing the average number of majors each year, over four years)

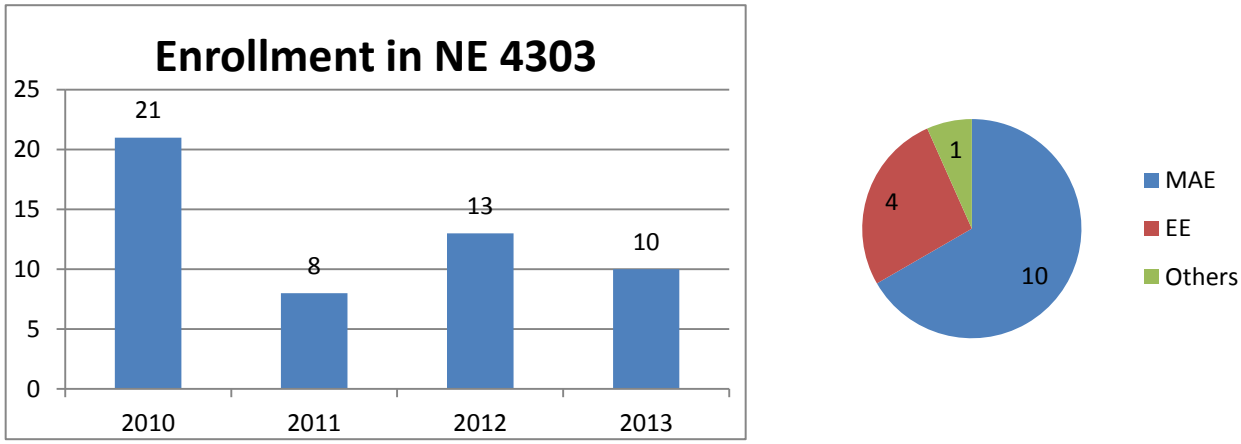

Fig 3. Enrollment in the third core course, NE 4303, during 2009–2012 and the enrollment by major (showing the average number of majors each year, over three years)

The enrollments for NE 4302 and NE 4303 are shown in Figs 3 and 4. As shown, only about 50% of the students continue to complete the program and earn the minor in NE. This drop is for several reasons: EE students can only use one of NE course for the EE degree, some students choose to graduate by the end of fall semester (rather than stay to complete the 2 additional core courses), and some are interested in only learning the fundamentals of nuclear engineering.

Impact of NE Minor at COE at UT Arlington

UT Arlington is a comprehensive research, teaching and public service institution whose mission is the advancement of knowledge and the pursuit of excellence. It is striving to attain national research university status. As such, the offering of additional engineering curriculum options

such as NE is completely in line with the university's mission. Since its initiation in fall 2009, the UT Arlington NE minor has begun contributing to the nation's NE education infrastructure. Indications are that interest will continue to be at a high level among our students in this minor, as shown in student surveys, class enrollments, large attendance at seminars where attendance was voluntary, and perceived interest among pre-college students.

In addition, the establishment of the NE minor has improved the educational infrastructure of the College of Engineering by the establishment of the Radiation Measurement Application Laboratory though a grant from the Department of Energy and an educational grant from the Nuclear Regulatory Commission (NRC) for web-based learning. Furthermore it has facilitated the establishment of collaboration with NRC Region IV in Arlington, Comanche Peak Nuclear Power Plant in Granbury, nuclear industries, national laboratories and other universities with stronger nuclear engineering programs.

References

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LYNN PETERSON

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