A Newly Developed Advanced Energy Concentration at Ohio Northern University

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Abstract
Energy is the key resource for the development and sustenance of an industrial society. The increasing demand for energy and the shrinking of nonrenewable energy resources result in the increasing importance of energy efficiency, energy conservation, renewable energy, and effective energy management policies. This changing environment in energy systems engineering requires engineering educators to develop and retrain the engineering workforce for the multidisciplinary background required for this field. In response to these challenges, Ohio Northern University (ONU) developed a concentration in advanced energy engineering. The concentration is open to students majoring in electrical, computer and mechanical engineering. This paper presents the curriculum of the developed concentration and lists required and elective courses as well. It is strongly believed that the mentioned development will result in a significant enhancement not only in the manner in which energy engineering courses are taught but also allow students to achieve higher levels of success to be industry-ready engineers.

Introduction
Energy resources, energy efficiency, and energy management have been an integral part of engineering education for over one hundred years. Over 80% of energy is currently obtained from non-renewable sources such as oil, gas, coal, and nuclear; these energy sources also have a significant negative impact on the environment. The power consumption needs of society are ever increasing. However, developing new traditional power generating plants and transmission lines to distribute the energy is becoming expensive, with increasing societal repercussions due to their environmental impact. In addition, renewable and alternative energy sources, such as solar, wind, or fuel cells, that can generate small to medium scale power, can be built near the local load centers or at individual user sites.

The Energy Independence and Security Act of 2007 states that it is the policy of the United States of America “To move toward greater energy independence and security, to increase the production of clean renewable fuels, to protect consumers, to increase the efficiency of products, buildings, and vehicles, to promote research on and deploy greenhouse gas capture and storage options, and to improve the energy performance …” [1]. The act highlighted the need to create new or modify existing academic programs to ensure availability of trained electrical, mechanical and computer engineers in areas such as plug-in electric vehicles (transportation), renewable energy (solar, geothermal, wind, biomass), light-emitting diode based luminaries and lamps (lighting), high-performance green buildings (heating and air-conditioning), energy storage, etc. Traditionally, electrical power is generated by large power stations located away from load centers and transmitted over long-distances via transmission lines at high voltages to distribution stations. The power is transmitted from the distribution stations to end users using shorter-distance distribution networks at medium/low voltages in a hierarchical manner as shown in Figure 1(a). The development of new transmission lines for increasing energy needs is
Renewable energy sources are becoming more popular because of their future potential of economic viability and generate energy locally with reduced need of new transmission lines; this is expected to be the model of future power grid as shown in Figure 1(b).

Figure 1 (a) Existing Power Grid, (b) Future Smart Grid with Distributed Generation [2]

The Department of Energy has proposed the use of “smart-grid” to improve the efficiency and reliability of future energy distribution [3]. The smart grid includes an intelligent monitoring system that keeps track of all electricity flowing in the system. The smart grid delivers electricity from suppliers to consumers using two-way digital technology to control appliances in consumers’ homes to save energy, reduce cost and increase reliability and transparency [4-9]. Distributed generation and storage in power grid is driven by the use of small to medium-scale renewable energy sources that can be integrated into the local grid. Therefore, the power distribution in the future will involve the effective use and integration of renewable energy sources. Research and development of these technologies requires graduates who have a first-rate education that accommodates the multidisciplinary nature of modern energy systems which involves diverse technical areas such as renewable energy sources [10], power engineering, wireless/power-line communication technologies [11-12], embedded systems [13-14], thermodynamics, heat transfer, digital control [15-16], and cyber-security [17]. Thus the education of a new generation of energy engineers will require a major transformation when compared to the current education approach that they are currently seeing.

The College of Engineering at ONU provides a strong undergraduate power engineering education in the electrical engineering program, complemented by thermal sciences education in mechanical engineering and embedded systems education in computer engineering. The strengths of the program have been recognized by American Electric Power (AEP) and NASA Glenn Research Center, who have sponsored a number of interdisciplinary senior design projects over the past few years. AEP further strengthened this commitment by providing a new $500,000 grant to the college to support the development of energy educational materials. This paper presents a new developed multidisciplinary concentration in advance energy engineering at Ohio Northern University.
The Developed Concentration
The concentration is open to students majoring in Computer Engineering, Electrical Engineering and Mechanical Engineering and builds on existing strengths of power engineering, thermal sciences, and embedded systems. The main objective of the concentration is to provide interdisciplinary education to prepare graduates to work in the energy industry. The concentration requires students to take both fundamental courses and elective courses. These courses complement the classes that they take in their respective programs to give them a solid background in this emerging field.

The concentration consists of seven courses, as shown in Table 1. Energy and Environment, Thermodynamics, and Energy Systems 1 are required of all students, regardless of major. Renewable Energy is a required course for ME and EE majors and can be taken as an elective for CPE majors. Courses marked by an asterisk will require completion of a one-credit independent study course to satisfy the prerequisites.

Students also take three or four elective courses from a list that varies slightly by major as shown in Table 2. The elective option is designed so that some elective courses must be taken outside the student’s major to expand their breadth of knowledge in energy systems. Courses in bold are outside the major. Note that for each major, the number of electives required is at least one more than the in-major offerings. Since some elective courses may only be taught in alternating years, the number of electives taken outside the major will likely be more than one. Courses marked by an asterisk will require completion of a one-credit independent study course to satisfy the prerequisites. Some of the courses needed to obtain a concentration in Advanced Energy Engineering will also satisfy major degree requirements. For the typical student, completion of the concentration will require approximately 5-9 credits beyond what is needed for their degree.

Table 1: Advanced Energy Engineering Concentration requirements by major.

| ME                        | EE                        | CPE                        |
|---------------------------|---------------------------|                           |
| Energy and Environment    | Energy and Environment    | Energy and Environment    |
| Thermodynamics            | Thermodynamics            | Thermodynamics            |
| Energy Systems 1*         | Energy Systems 1          | Energy Systems 1          |

Table 2: Advanced Energy Elective courses by major.

| ME                        | EE                        | CPE                        |
|---------------------------|---------------------------|                           |
| Smart Grid*               | Smart Grid                | Smart Grid                |
| Advanced Power            | Advanced Power            | Advanced Power            |
| Photovoltaic/Power Devices*| Photovoltaic/Power Devices| Photovoltaic/Power Devices|
| Nuclear Physics           | Heat Transfer*            | Heat Transfer*            |
| Microprocessors*          | Network & Security        | Network & Security        |
| Energy Systems 2          | Energy Systems 2          | Renewable Energy*         |
Energy and Environment: Current fuel sources: fossil fuels, nuclear, and hydroelectric; economic and environmental cost, and safety; energy efficiency, alternate energy sources, components of the power grid, will be explored.


Energy Systems 1: Analysis, performance characteristics, operation principles, and applications of power transformers, rotating machines, converters, inverters, and switched-mode power supplies. Computer Simulation. Integrated laboratory experience.

Energy Systems 2: Power systems fundamentals, single line diagrams and per unit calculations, transmission lines modeling, load flow techniques, economic dispatch, fault analysis, and power systems control. Computer simulation.

Heat Transfer: Principles of the three mechanisms of heat transfer (conduction, convection, radiation) in solid, fluid, and vacuum media. Development of control volume approach as well as numerical solution techniques.

Microprocessors: Microprocessors and microcontroller system design, microprocessor structure, registers, RAM and ROM addressing, machine cycles and timing relationships, Input and output ports and addressing, assembly level programming, Embedded C programming, microcontroller structure, timer systems, analog-to-digital converters, serial and parallel communication, use of development systems and design simulators, embedded microcontroller design projects;


Renewable Energy: An overview of renewable energy sources such as solar, wind, water, and biomass. Current and potential technologies for extracting, storing, and converting renewable energy into electricity. Economic and social issues that impact renewable energy projects.

Networks and Security: Network deployment and coverage; localization; clock synchronization; wireless link quality; medium access and topology control; data-centric networking, transport reliability and congestion control; security in wireless sensor networks.

Advanced Thermodynamics: Application of thermodynamic laws to the analysis of advanced cycles and processes. Modifications to the basic Rankine, Brayton and piston engine power cycles, including topping cycles and cogeneration. Basic and advanced refrigeration and heat pump cycles.

Advanced Power: This course will alternate between selected topics in power engineering and electric drives.
Nuclear Physics: Nuclear structure, nuclear reactions, nuclear constituents, fundamentals of nuclear reactor theory and design, shielding and safety principles in nuclear physics.

Smart Grid: Smart grid for efficient power system; resource adequacy and transmission planning; energy efficiency at power production and delivery; wind/solar power forecasting; integration of intermittent renewable sources; DC distribution; probabilistic reliability evaluation; energy storage; microgrids; demand side management; energy efficiency: electric end use; smart and sustainable Buildings; cyber-physical systems; cyber-security in energy grid.

Conclusion
This paper presented a newly developed advanced energy concentration at Ohio Northern University. Since educational reform in the energy field is sorely needed and graduates with this knowledge will be highly recruited by the power industry, students will be motivated to enroll in the concentration. It is strongly believed that the concentration outcome is directly responsive to the need of the power industry of well-trained and highly skilled graduates.

REFERENCES