EEE 564 Interdisciplinary Nuclear Power Operations (3 hrs)

Catalog Description: Nuclear power plant systems. Study of the interrelationship and propagation of effects that systems and design changes have on one another, especially in relation to nuclear power plant safety and operations. Case studies and design projects.

Pre-requisites: Fundamental knowledge and understanding of nuclear power engineering.

Course Objective: Instill the fundamental concepts and importance of nuclear safety to engineers and scientists in a variety of disciplines.

Course Outcomes:

- Students are knowledgeable about nuclear power plants and their safety systems.
- Students are cognizant of the critical role of that engineers have on the safe operation of a nuclear power plant.
- Students are prepared for the impacts that various engineering processes (changes and failures) have across the entire power plant.

Reading Materials: R. A. Knief, *Nuclear Engineering: Theory and Technology of Commercial Nuclear Power*, 2nd Edition, American Nuclear Society, 2008, 770 p. And course reading materials to be developed as part of the U.S. Nuclear Regulatory Commission grant in cooperation with industrial partners at the Palo Verde Nuclear Generating Station.

Course Topics:

Week	Topic Description
1	Nuclear Safety and Risk Overview
2	Nuclear Power Plant Systems
3	Licensing, Regulatory Issues, Standards
4	Emergency Preparedness and Response
5	Plant Emergency and Safety Systems
6	Integrated Plant Operations
7	Materials Corrosion, and Chemical and Volume Control
8	Instrumentation and Controls
9	Human Factors
10	Plant Modifications
11	Radioactive Waste Generation and Effluent Monitoring
12	Industry Events
13	Probabilistic Safety and Risk Assessment
14	Security
15	Grid Disturbances
	One midterm and one final examination

<u>Detailed Topical Outline</u>

1. *Nuclear Safety and Risk Overview* – will instill the fact that the basic objective of reactor safety is to prevent the release of radionuclides so that the operation of nuclear power plants does not contribute significantly to individual and societal health risks, and that the basic strategy to accomplish this is to prevent fuel overheating. The concept and quantification of risk will also be presented.

2. *Nuclear Power Plant Systems* – will provide an overview of traditional (Generation II) pressurized water reactors (PWRs) and boiling water reactors (BWRs) as well as the new Generation III plants viewed as most likely to be built in the U.S, including Westinghouse's AP1000, General Electric's advanced boiling water reactor (ABWR) and economic simplified boiling water reactor (ESBWR), Areva's evolutionary power reactor (EPR), and Mitsubishi's U.S. advanced pressurized water reactor (US-APWR). This topic is covered early in the semester so that each student begins with the knowledge necessary to understand the context of the systems and components applicable to nuclear plant operation.
3. *Licensing, Regulatory Issues, Standards* – shall cover the role of organizations such as the Nuclear Regulatory Commission (NRC), the Institute of Nuclear Power Operations (INPO), the World Association of Nuclear Operators (WANO), standards organizations (ANSI, IEEE, ANS, ISA, ASME, ASTM); the one-step (10 CFR Part 52) licensing process; requirements for and need to update the plant safety analysis report; and quality assurance.
4. *Emergency Preparedness and Response* – will address the procedures and plan for plant operations during emergencies, including those due to natural occurrences, as well as the NRC emergency classification levels. A current topic in this area is hostile action (terrorism) emergency preparedness.
5. *Plant Emergency and Safety Systems* – will begin by examining the differences between inherent, passive and engineered (active) safety features. Plant safety systems from a high enough level to be applicable across all reactor vendors will then be presented; this shall include low-pressure and high-pressure emergency core cooling systems, containment isolation and cooling systems, and core protection system. A possible case study for this topic concerns the PVNGS essential spray pond fouling.
6. *Integrated Plant Operations* – will provide student with overall knowledge of plant equipment operation and assist them in developing a better understanding of transients and accident sequences applicable to nuclear power plant operation.
7. *Materials Corrosion, and Chemical and Volume Control* – chemical and volume control of the reactor coolant system can have far-reaching effects on materials, including issues with stress corrosion cracking (SCC). Case studies will include the reactor vessel head degradation at the Davis-Besse Nuclear Power Station and the leakage from reactor vessel lower head at South Texas Project Unit 1.
8. *Instrumentation and Controls* – there is considerable regulatory interest in digital instrumentation and controls due to proposed retrofits to existing nuclear power plants and the plans for all-digital systems in the new plants. The industry is presently undertaking significant efforts in this area and is expected to continue to do so into the near future given the issues (e.g., common cause failure due to software errors) that present themselves in qualifying digital technology for nuclear reactor safety systems. The recent process behind and the installation of digital feedwater controllers at PVNGS will make an excellent case study for this topic.
9. *Human Factors* – will examine issues such as human performance in engineering, shift work impact and fitness-for-duty. Control room modifications and the use of control room simulators will also be addressed.
10. *Plant Modifications* – clearly retrofits and modifications to the plant require re-analysis of impacted features. A very good case study for the nuclear power industry is the process of power uprating. Part of the reason for using this as a case study is that there are three different levels of power uprates: (1) measurement uncertainty recapture (<2% power uprating) for implementation of enhanced techniques for computing reactor power using more accurate flow sensors, (2) stretch power uprates (<7%) using changes to instrumentation setpoints, and (3) extended power uprates (<20%) in the case of significant equipment modifications. Increasingly larger uprates require an increasing amount of re-analysis due to the greater impact plant-wide.
11. *Radioactive Waste Generation and Effluent Monitoring* – the effectiveness of plant operations has a direct impact on the generation of low-level wastes and the concomitant need for monitoring

effluents from the plant. A current topic in the nuclear industry is the contamination of groundwater via unintended releases of tritium.

12. *Industry Events* – will address current topics and operating experience in the nuclear power industry, including reactor license renewal, and new reactor licensing. A current issue regarding emergency systems is whether debris can accumulate on the containment sump screens in PWRs from a loss-of-coolant accident. Such an occurrence would impede the return water flow to the low-pressure emergency core cooling and containment spray systems. Students will review operating event reports (LERs) and the processes used to mitigate or correct the incident, and formulate solutions to ensure that the event or incident does not reoccur.
13. *Probabilistic Safety and Risk Assessment* – Introduction to success criteria determination for safety related power plant systems, development of initiating event frequency, event and fault tree development and quantification, common cause, human reliability, uncertainty analysis, component failure analysis and dayesian update techniques, fundamentals of reliability techniques as applied to common engineering problems at nuclear power stations.
14. *Security* – the security aspects of nuclear power plant operations can be addressed within the course in a generic form without the need to reveal sensitive plant-specific information. However, the nationally publicized incident at PVNGS in which a pipe bomb was discovered in the truck of a contract worker can be used as a case study. The pipe bomb was found during a routine screening at the security checkpoint of the plant-site entrance—this incident resulted in an unusual event being declared in November 2007.
15. *Grid Disturbances* – in examining the interaction of various systems on power plant operations, another impact point is the affect that disturbances in the electric power system have on the power plant. With the increasing desire to add intermittent green energy sources such solar and wind, there is a possibility of more grid disturbances such as that experienced by Texas in February 2008.
16. *Exams* – both a midterm and final exam will be administered. These exams will not only allow the instructor to evaluate the knowledge and proficiency of the student, but also to assess (and improve) the course itself.

Assessment (Grading) of Students: Homework (25%), mini projects (30%), and two exams (20%+25%).