INSA Centre Val de Loire, Industrial Risk Control (MRI)

5th year Nuclear Energy option syllabus

(18 ECTS)

1. Teaching Unit: Non-linear mechanics and nuclear physics (MO_SFENU1)

1.1 Module: Mechanical modeling – geometric nonlinearities (24h)

Summary
Introduction to modeling the geometric nonlinear behavior of deformable structures.

Outlines
- General notions and examples of different geometric non-linearities
- Notations, description of geometric variables
- Continuum mechanics
- Finite element method and examples of applications.

1.2 Module: Mechanical modeling – material non-linearities (24h)

Summary
Introduction to the modeling of irreversible phenomena of solid mechanics.

Outlines
- Modeling tools
- Elastoplasticity
- Elastoviscoplasticity
- Damage

1.3 Module: Structures vulnerability (24h)

Summary
Principles of the use of dynamic actions in structures computation.

Outlines
- Consideration of dynamic actions in solids
- Methods for determining the response of a structure

1.4 Module: Nuclear and neutronics physics (26h)

Summary
The objective is to provide the basic theoretical knowledge essential to the understanding of nuclear energy. This course deals in a first part with nuclear physics and then presents in a second part the basics of neutronics in the field of atomic engineering.

Outlines
- History: What is nuclear physics?
- Matter constitution
- Time and length scales and fundamental interactions
- Matter organization at the nucleus level

- Instability and radioactivity
- Neutron-induced nuclear reactions
- Application of the concept of the (macroscopic) cross section
- Nuclear data, uncertainties, covariances
- Phase space, flux definition, current, neutron density, neutron balance
- The Boltzmann equation for neutrons
- Fuel evolution

1.5 Module: Physics of nuclear reactors (20h40)

Summary

The main concepts covered are the components of a nuclear reactor core (nuclear fuel, coolant, reflector, absorbent) as well as the physics allowing the control of the nuclear reactor.
A short part is dedicated to an introduction to the development of thermonuclear fusion.

Outlines

- Neutronics reminder
- The components of a nuclear reactor,
- Static Reactor Theory,
- The kinetics of the reactors,
- The dynamics of reactors.

2. Teaching Unit: Safety, security and environment (M09O_SFENU2)

2.1 Module: Functioning and safety (18h)

Summary

Through a presentation of the main components and systems that make up a Pressurized Water Reactor (PWR), the objective of this module is to understand the different concepts related to the issues and arrangement (e.g. for operational and degraded modes) of an electronuclear process, thus giving an overview of the operation of a PWR (in France).

Outlines

- General information and nuclear safety
- PWR design: conventional part
- PWR design: the nuclear island
- Power operation
- Degraded mode – serious accidents

2.2 Module: Integrity and reliability analysis - Safety, accidentology and crisis (24h)

Summary

The objective is to present the principles of nuclear security and some monitoring tools which make it possible to ensure or improve security. In particular, the differences between the Pressurized Water Reactor (PWR) in France and the European Pressurised Reactor (EPR) are discussed.
Secondly, the major accidents that have occurred at the Three Mile Island, Chernobyl and Fukushima Daichi nuclear power plants are presented and analysed. Through the Fukushima case, the progress made in preventing the risk of hydrogen explosion is detailed.

Outlines

- Nuclear security

- EPR introduction
- Major accidents
  - The Three Mile Island and Chernobyl accidents and the lessons learned for the safety of nuclear plants in France
  - The Fukushima Daichi accident: state of knowledge

2.3 Module: Safety of reprocessing / recycling (18h)

Summary

The objective is to get into the study of nuclear fuels and recycling under the aspects of economic stakes, technology, chemical and nuclear risks, and constraints.

Outlines

- The purpose of recycling reprocessing,
- General presentation of the nuclear fuel cycle,
- The reprocessing process,
- Risk control,
- Safety and radiation protection in design and construction,
- Safety and radiation protection in operation,
- The management of incidental or accidental situations,
- Environmental protection.

2.4 Module: Safety of facilities and radioactive materials (22h)

Summary

The objective is to present the control of nuclear risks at the level of reactors, nuclear plants and the transport of radioactive materials. First, we introduce the main principles of security and to the various actors involved in the organization of security both at national and international level. Secondly, the specificities of each field are discussed.

Outlines

- Major safety principles,
- France and international actors,
- Safety of facilities in the upstream nuclear fuel cycle,
- Safety of nuclear reactors,
- Safe transportation of radioactive materials,
- Probabilistic safety study.

2.5 Module: Protection of the human health and of the environment (28h)

Summary

This module covers the various aspects of the management of human exposure to ionizing radiation and environmental contamination. First, a presentation of radiobiological protection which notably introduces the principles and standards in this field and defines the different quantities used. The different means of radiation detection and characterization are then presented. Finally, the impact on the environment, the treatment of abnormal radiological situations and the ALARA principle are discussed.

Outlines

- Radiobiological protection,
- Detectors of particles resulting from nuclear reactions
- Dosimetry and dosimeters,
- Environmental impact,
- Treatment of abnormal radiological situations,
- The ALARA principle.