Course Specifications
Valid as from the academic year 2015-2016

Safety of Nuclear Power Plants (E038601)

Course size
Credits 5.0
Study time 150 h
Contact hrs 50.0 h

Course offerings and teaching methods in academic year 2018-2019
A (semester 2)
English
lecture
50.0 h

Lecturers in academic year 2018-2019
Druenne, Hubert
TW08
lecturer-in-charge

Labeau, Pierre-Etienne
ULB522
co-lecturer

Offered in the following programmes in 2018-2019
Master of Science in Nuclear Engineering
5
A

Teaching languages
English

Keywords
Nuclear safety, Reliability, PWR technology, PSA methodology

Position of the course
To learn how to operate a nuclear reactor. To learn the reactivity change of a reactor core during a burn-up cycle. To learn the basics of core reloading. Emphasis will be placed on PWR-technology.

Contents
Operation & Control
• Cycle specific safety evaluation methodology.
• Basic principles of the in-core fuel management based on the linear reactivity model.
• Reactivity coefficients (moderator, Doppler), neutron poisons (xenon, samarium, ...), their variation with burnup and core state parameters and their impact on core power distribution.
• Reactivity control means (boron, control rods, burnable poisons) and their sensitivity to the core burnup and in-core fuel management parameters.
• Operating modes, operating limits and protection diagram.
• Fuel rod design and thermal-mechanical behavior in normal operation and accidental conditions.
• Core thermal hydraulics: thermal-design procedures and elaboration of the core thermal limits and core protections.
• Measurement systems and their specificities in the nuclear reactor.
• Core control, surveillance and protection systems and their performance in transient and steady-state operation.
• Seminar on the major Design Base Accidents, consequences and mitigation.
• Seminar on reload calculations: tools used and economic considerations.
• Visit of a Nuclear Power Plant.
• Two day session of compact and full scope Nuclear Power Plant simulator.

Reliability & Safety
• Introduction to nuclear safety: hazard sources, safety functions, safety systems, defence in depth, line of defence method.
• Safety goals and risk based criteria: the concept of risk, individual and societal risk criteria, release limits, core damage frequency limit, safety goals at function or system level.
• The safety design cycle: (conservative) deterministic analysis based on design basis accidents and (best estimate) analysis of beyond design basis events; probabilistic analysis as a review of the safety design.
• Overall process of probabilistic safety assessment (PSA): PSA level 1, 2 and 3.

(Approved)
• Qualitative analysis: hazard and scenario identification methods (FMEA, HAZOP, Event trees..)
• Component reliability: basic RAMS concepts, failure and repair time distributions, estimation of parameters from real life data, uncertainty bounds, Bayesian estimation of parameters
• Systems reliability:
  • Fault tree analysis: fault tree construction, coherence of fault trees, logical and probabilistic analysis of fault trees, system unavailability, expected number of failures, criticality of events and minimal cut sets,
  • Markov analysis: state diagrams, transition matrices, determination of system unavailability and system
  • Common cause failure analysis: type of dependencies, qualitative and quantitative analysis of common cause failures
• Elements of human reliability analysis
• Accident sequence analysis: event trees, determination of sequence frequencies and plant response
• Elements of PSA level 2 and level 3 methodology
• Exploitation of PSA results

Initial competences
The following BNEN courses are a prerequisite: • Nuclear reactor theory • Nuclear thermal hydraulics

Final competences
Operation & Control
• To understand how to insure the link between nuclear safety and reactor operation.
• To understand the main fuel related design and safety limits in normal operation and accidental conditions, the resulting limits on the core power distribution and their impact on the core control, surveillance and protection designs.
• To master all the contributors to the core reactivity balance and power distribution in normal operation.
• To study specific problems of measurement and control in nuclear reactors.

Emphasis is on PWR technology
Reliability & Safety
• To present elements of nuclear safety philosophy.
• To present the approach for embedding safety in design of nuclear facilities and to perform safety analysis (both deterministic and probabilistic).
• To learn the basic notions and techniques of system reliability engineering.
• To understand the fundamentals of probabilistic safety analysis (PSA).
• To be able to assess the overall quality of the PSA methodology.

Conditions for credit contract
This course unit cannot be taken via a credit contract

Conditions for exam contract
This course unit cannot be taken via an exam contract

Teaching methods
Lecture

Learning materials and price
The PowerPoint presentations of the lectures, and extensive lecture notes, are available on the BNEN website.

References

Course content-related study coaching

Evaluation methods

(Approved)
end-of-term evaluation and continuous assessment

Examination methods in case of periodic evaluation during the first examination period

Open book examination, oral examination

Examination methods in case of periodic evaluation during the second examination period

Open book examination, oral examination

Examination methods in case of permanent evaluation

Assignment

Possibilities of retake in case of permanent evaluation

examination during the second examination period is possible in modified form

Extra information on the examination methods

**Operation & Control Individual**

Oral exam, closed book, written preparation

**Reliability & Safety**

Two parts each counting for half of the quotation marks: • A practical exercise to be prepared by the student covering the subject of reliability assessment and to be sent in to the teacher; • An oral examination (open book) on the understanding of the concepts treated in the course

Calculation of the examination mark