



**Máster Universitario en “Ciencia y Tecnología Nuclear”**

**Master Erasmus Mundus SARENA (Safe and Reliable Nuclear Applications)**

**ADVANCED SEMINAR**

**“Nuclear Safety concepts and their application”**

**Dr. Gustavo RUBIO ANTÓN**

Senior expert on nuclear safety and licensing

Dr Gustavo Rubio Antón holds a Master’s Degree in Mechanical Engineering from the University Carlos III of Madrid and a PhD in Electromechanical Engineering from the Catholic University of Leuven, Belgium.

He has developed his career in the nuclear sector mostly in Belgium and the United Kingdom over the last 12 years. As a nuclear safety engineer he has worked in new build projects such as the construction of two EPR reactors at Hinkley Point C in UK, resilience enhancements to the UK and Belgian fleets of PWRs following the Fukushima stress tests, or the Long Term Operation of units Doel 1&2 in Belgium. He has worked on the technical and economic assessment of advanced nuclear technologies and advised Governments on policy matters related to the deployment of these type of reactors. At present, he is responsible for the pre-licensing of the MYRRHA reactor in Belgium, a fast, heavy metal cooled, accelerator driven first of a kind system.

He is a fellow of the UK Institution of Mechanical Engineers, a member of the OECD Working Group on the Safety of Advanced Reactors and has been invited to lecture on nuclear safety in prestigious institutions such as the University of Bristol in the UK and the Polytechnic Institute of Milano in Italy.

**Tuesday 8, Wednesday 9, Thursday 10 June, from 15:30 to 17:30 (CET)  
Friday 11 June from 10:00 am to 12:00 (CET)**

This Seminar will be face-to-face in a classroom to be announced. If the COVID-19 conditions do not allow the face-to-face activity, it would be developed online in MS-Teams

## Advanced Seminar on Nuclear Safety concepts and their application

Dr Gustavo Rubio Antón

### Description:

This 8 hours seminar provides an understanding of the concept of nuclear safety and of the techniques used to justify the safety of the nuclear installations during design, construction, commissioning, operation and dismantling. The course will provide some historical background that will allow the students to understand how nuclear safety requirements have evolved and with them the techniques used to demonstrate compliance with nuclear safety requirements. Important concepts such as Defence-in-Depth and ALARP will be introduced and described in detail together with the tools and techniques used to justify that the overall risk posed by nuclear installations is within the boundaries of acceptability set by regulators.

### Intended Learning Outcomes:

The students will be able to:

1. Describe concepts of nuclear safety such as design basis, defence-in-depth, graded approach and safety classification;
2. Understand the philosophy of Defence-in-Depth and the application of graded approach;
3. Understand the type and nature of hazards and initiating event threatening the safety of nuclear installations;
4. Discuss the engineering principles upon which nuclear safety is based such as redundancy, diversity, single failure, common cause failure, segregation, separation and qualification;
5. Get familiar with generic nuclear safety requirements and the safety functions that need to be delivered to achieve compliance with those requirements;
6. Understand the difference between the safety functions and the structures, systems and components delivering those functions;
7. Have a basic understanding of the probabilistic and deterministic analytical techniques used to provide the evidence that will underpin safety claims;
8. Understand how the safety case is translated into technical specifications and operational procedures used by operators to maintain the plan within the prescribed regulatory limits.

### Teaching details:

Through lectures. The seminar is structured in four lectures of 2 hours each.

#### Lecture 1: *Historical perspective and basic concepts of nuclear safety*

The initial lecture will give the students historical perspective on how the nuclear safety requirements have evolved since the Chicago Pile 1 became critical in 1942 until today. The events in Three Mile Island, Chernobyl and Fukushima will be described more in detail and the students will discuss what the industry has learnt from each of those accidents in terms of nuclear safety. The unit will show how reactor design has advanced from considering only design basis events to the introduction of requirements for beyond design basis and severe accident analysis. Practical examples will illustrate how operational experience has stressed out the importance of concepts such as human factors, safety culture and emergency preparedness.

Building on that historical perspective, the lecture will discuss the concepts of risk and safety. The classical definition of risk in terms of probability of occurrence and severity of consequences will be used. The discussion will focus on how to deterministically reduce the risk to tolerable levels and how to manage the

residual risk. The concept of ALARP will be introduced and discussed from the perspective of the designer and the regulator. The students will also get familiar with concepts such as normal operation, anticipated operational occurrence, design basis, beyond design basis and severe accident, and with the expectations for the plant in terms of radiological consequences during each of those stages of the evolution of an accident.

### **Lecture 2: Defence-in-Depth and graded approach**

The lecture will introduce the three fundamental safety functions and will discuss how, by delivering those safety functions, the integrity of the physical barriers that separate the radioactive materials from the people and the environment is ensured. The concept of Defence-in-Depth will then be described in detail as an overall strategy for the management of safety in nuclear power plants. The different layers of Defence-in-Depth will be discussed and illustrated by means of examples. The lecture will discuss the qualitative and quantitative safety objectives that need to be met in each layer and how these objectives are defined by regulators.

The discussion will evolve into how the fundamental safety functions previously introduced break down into plant level safety functions that need to be categorized according to their importance to safety. The criteria for the categorisation will be introduced and discussed. The lecture will then describe the relation between these safety functions and the structures, systems and components (SSCs) responsible for delivering them, and how these also need to be classified according to the importance of the safety function that they contribute to deliver. Through practical examples of real safety systems the students will understand how the safety classification of a particular item imposes requirements on the design, construction, commissioning, operation and maintenance of that item.

### **Lecture 3: Engineering safety concepts**

In the previous lecture, the students have become familiar with the concept of safety classification and the requirements imposed on SSCs depending on their safety class. This unit will elaborate further by discussing the engineering safety principles that might apply to safety classified plant items, their meaning, how to implement them and the role they play in the safety case. Concepts such as common cause failure, single failure, redundancy, diversity, physical separation and segregation will be discussed. Documents such as ANSI standards or US NRC Regulatory Guides will be used to illustrate the way these concepts are embedded into prescriptive regulations. The unit will also discuss the environmental qualification requirements for classified SSCs and how these are dependent on the expected level of the hazard, but also on the environmental conditions on which the SSC is expected to deliver the safety function. The capability, reliability and functionality requirements for the relevant operational states where classified SSCs are credited will also be discussed.

### **Lecture 4: Probabilistic safety analysis and plant safety documentation**

This lecture will introduce the three levels of PSA and explain the objectives of each of them (the estimation of core damage frequency, release categories and off-site radiological consequences respectively) together with the tools and methods used in nuclear power plant's PSA.

The role of PSA will be discussed in terms of:

- Establishing the risk profile of the plant by estimating core damage frequencies and the conditional probability of radiological releases;
- Identifying components or systems whose unavailability significantly contributes to core damage frequency;
- Understanding the amount and severity of residual risk;

The students will not learn in this unit how to build a PSA, but how a PSA is used to make decisions and the importance it has to justify the safety of the installation during licensing and operation.

The last part of the lecture will discuss how the concepts discussed during the seminar are translated into safety documentation that is used by plant operators to maintain the plant within the safety envelope approved by the regulator. The students will become familiar with the derivation, meaning and use of Technical Specifications and operational procedures for normal and accidental conditions and also for the testing of safety related system, structures and components.

### **Reading and References:**

- Introduction to Nuclear Power, G.F. Hewitt and J.G. Collier, CRC Press; 2nd edition (2000).
- Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactor Plants - ANSI/ANS-51.1
- Defence-in-Depth in Nuclear Safety – IAEA International Nuclear Safety Advisory Group – INSAG 10
- Standard Technical Specifications – NUREG-1431
- Deterministic Safety Analysis for Nuclear Power Plants – IAEA Safety Standards – SSG-2
- Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants. IAEA Safety Standards – SSG-3.