Impianti Nucleari I (a.y. 2017-2018)

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PRE-REQUISITES
It is advisable to have passed the exam of "Principi di Ingegneria Nucleare".

COURSE OBJECTIVES
The main objective of the course is to give an overall vision of the nuclear technology relating to the existing Nuclear Power Plants. In particular, this course is intended to understand the engineering design of nuclear power plants using the basic principles of reactor physics, thermodynamics, fluid flow and heat transfer.

The course is organized in seven main parts, described in the following.

Part I – General overview of NPPs (about 4 hours)
NPPs under operation in the world, forthcoming reactors and license renewals, GreenHouse Gas (GHG) emissions for various electricity generation sources, waste generation. Generation costs. Nuclear installations in France and in Italy. Generation of NPPs, classification of nuclear reactors on the base of energy spectrum, purpose, fuel, coolant, moderator, etc.. Typical data characteristic of NPPs.

Part II - Boiling heat transfer and two-phase flow overview (about 8 hours)
First definitions, homogeneous nucleation, heterogeneous nucleation, pool boiling regimes, pool boiling curve, heat transfer correlations for pool boiling. Flow boiling and two-phase flow: first definitions (void fraction, superficial velocity, flow quality, slip ratio, thermodynamic equilibrium quality and two-phase density). Boiling channel, two-phase flow regimes, flow pattern maps, flooding and flow reversal, heat transfer regimes in the boiling channel, Chen correlation, CHF (DNB and DRYOUT), flow boiling curve, main CHF correlations, Minimum CHFR. 1D Balance equations for two-phase flow, components of pressure drop, friction pressure gradient and two-phase multiplier, pressure drop in a heated boiling channel.

Part III - Pressurized Water Reactors (about 16 hours)
Short history, reactor coolant system, coolant path inside the vessel, reactor vessel, internals, pressurizer, steam generators, VVER, reactor containment building, coolant pump, nuclear fuel, fuel pin and fuel assembly, control rods, burnable absorbers. Refuelling scheme and spent fuel, reprocessing, nuclear fuel cycle, thermodynamic cycle, steam turbine for NPP, steam condenser. CVCS, RHRS, ECCS, AFWS, CSS, Physical barriers in the defence-in-depth, inherent safety features of a NPP: core under-moderated and over-moderated.

Part IV - Boiling Water Reactors (about 12 hours)
Short history, Reactor Coolant System, comparison with PWR, recirculation system and jet pumps, Reactor Vessel and internals, fuel assembly, fuel rods, water rods, fuel enrichment, core characteristics, control rods. Reactor containments (dry, Mark I, Mark II and Mark III), comparison between the different containment types. Short presentation of Fukushima Daiichi accident. Reactor Water Cleanup System, Standby Liquid Control System, Reactor Core Isolation Cooling, Emergency Core Cooling Systems, RHR System.

Pat V - Reactivity, reactivity coefficients and fission product effects (about 6 hours)
Short review about the fission process, cross section and effective multiplication factor. Definition of reactivity and conventional unit of measure. Reactivity coefficients: fuel temperature, moderator temperature, void, pressure, power. Reactivity defect. Fission product effect on the reactivity of a NPP: burnup effect.

Part VI - Pressurized Heavy Water Reactors – CANDU (about 8 hours)
Short history, evolution of CANDU, Heat Transport System, moderator properties and motivation for the separation between coolant and moderator, comparison between CANDU and PWR. Feeder, header, steam generator, primary pump, calandria and core configuration, moderator cooling system, fuel bundle, fuel element, sheath, evolution of CANDU fuel bundle, mining to spent fuel storage, fuel channels arrangement in the calandria, fuelling machine, refuelling and heat flux distribution. Reactivity devices for CANDU 6, shutdown systems. Some safety requirements of the PHT, LOCA event and Emergency Core Cooling System, Reactor Containment. Good and bad features design of CANDU, Nuclear Safety Characteristics, reactivity coefficients.

Pat VII – Graphite-Moderated Reactors (about 6 hours)
Graphite used as moderator. Short history of GCR. MAGNOX reactors; Advanced Gas-cooled Reactors (AGR); High Temperature Gas-cooled Reactors (HTGR): TRISO fuel, Pebble Bed and Prismatic Reactors, Modular HTGR. RBMK reactors.

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