EDUCATION AND TRAINING ON ISIS RESEARCH REACTOR

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ABSTRACT

In the frame of academic and vocational programs the National Institute for Nuclear Science and Technology uses the ISIS research reactor as a major tool to ensure a practical and comprehensive understanding of the nuclear reactor physics, principles and operation. A large set of training courses have been developed on ISIS, optimising both the content of the courses and the pedagogical approach. Programs with duration ranging from 3 hours (introduction to reactor operation) to 24 hours (full program for the future operators of research reactors) are carried out on ISIS reactor. The reactor is operated about 350 hours/year for education and training, about 40 % of the courses being carried out in English. Thus, every year about 400 trainees attend training courses on ISIS reactor. We present here the ISIS research reactor and the practical courses that have been developed on ISIS reactor. Emphasis is given to the pedagogical method which is used to focus on the operational and safety aspects, both in normal and incidental operation. We will present the curricula of the academic and vocational courses in which the practical courses are integrated, the courses being targeted to a wide public, including operators of research reactors, engineers involved in the design and operation of nuclear reactors as well as staff of the regulatory body. We address the very positive impact of the courses on the development of the competences and skills of participants. Finally, we describe the Internet Reactor Laboratories (IRL) that are under development and will consist in broadcasting the training courses via internet to remote facilities or institutions.

1. Introduction

Part of the French Alternative Energies and Atomic Energy Commission (CEA), the National Institute for Nuclear Science and Technology (INSTN) is a higher education institution [1]. Its objective is to provide students and professionals with a high level of scientific and technological qualification in all disciplines related to nuclear energy applications. In this frame, INSTN carries out education and training (E&T) programs on nuclear reactor theory and operation. Its strategy is to complete theoretical courses by training courses and laboratory works carried out on an extensive range of training tools that includes software applications, simulators, as well as the use of research reactors [2, 3]. For all of the practical exercises, specific emphasis is given to the safety issues aspects of reactor design and operation, both in normal and incidental operation [4].

From 1961 till 2007, the INSTN was operating its own reactor, an Argon type 100 kW reactor called ULYSSE. In 2007, the Education and Training (E&T) activity was transferred to the

ISIS research reactor which is operated by the Nuclear Energy Division. For this purpose, the ISIS reactor went through a major refurbishment from 2004 till 2006.

This paper presents the characteristics of the ISIS reactor. It describes the curricula of the academic and vocational courses in which the practical courses are integrated, and addresses the very positive impact of the courses on the development of the competences and skills of participants. Finally, this paper presents the Internet Reactor Laboratories (IRL) that is under development and will consist in broadcasting the training courses via internet to remote facilities or institutions.

2. The ISIS research reactor

The ISIS research reactor is located on the CEA Saclay site. It belongs to the same nuclear facility as OSIRIS reactor and is operated by the Nuclear Energy Division. Both reactors are open core pool type reactors and exhibit the same core characteristics (size and configuration of the core, fuel and rod characteristics). However, from the thermo-hydraulic point of view, ISIS reactor has a nominal power of 700 kW and can cork on demand, while OSIRIS, which is a multipurpose reactor, is operated at 70 MW by cycles of 18 to 25 days.

The schematic of ISIS reactor pool is shown in Figure 1-a. The pool of ISIS reactor is 7 meter deep. At the bottom of the pool, a big metallic piece called the base sustains the core of the reactor. An array of holes in the base can be used to insert experimental devices in different location around the core. The core has a horizontal section of 62 cm x 70 cm and a height of 65 cm. It is composed of an aluminium box with 56 cases which is included in a zirconium alloy container. The core contains 38 fuel assemblies, 6 control rods, 7 Beryllium assemblies, as well as 5 experimental cases (see Figure 1-b). The MTR (Material Testing Reactor) type fuel, in silicide U_3Si_2Al form, is enriched at 19.75 %. The active part of the fuel assembly has a height of 65 cm.

The control rods are moved through mechanisms that are placed above the core. They have a particular design since they include a lower part that contains fuel in addition to the upper part that contains hafnium used to capture neutrons. Thus, when moving up a rod out of the core, the removal of the rod results both in the removal of absorbing material and the introduction of extra fuel in the core.

The beryllium assemblies, placed on one side of the core, are used both as a neutron reflector, to reduce the neutron leakage, and as the starting neutron source, through (γ, n) reactions with beryllium. In addition, this beryllium wall coupled with the fuel configuration is used to obtain a non-uniform neutron energy spectrum in the core, i.e. a larger contribution of slow neutrons in the vicinity of beryllium.

The experimental cases can be used to place devices to be irradiated or tested (instrumentation, samples to be activated, test fuel …). In their basic state, the case is filled with a plain aluminium box which exhibits the same dimension as a fuel assembly and contains four plain aluminium cylinders (28 mm in diameter) that can be removed separately to introduce small samples or devices in the core.

The reactor is equipped with 4 neutron detection systems that are placed in metallic tubes found above the top of the core on the beryllium assembly's side. The low level detection system (BN1 & BN2), equipped with fission ionization chambers working in pulse mode, can be operated up to a power of 40 W. The high level detection systems (HN1 & HN2), equipped with boron ionization chambers working in current mode, can be operated from about 1 W up to the nominal power. Extra detectors can be installed in an additional tube found between HN1 and HN2 or in tubes that can be inserted in or around the core.

Above the core a stainless steel chimney separates the water from the primary water loop from the rest of the pool. A gate, which is placed on one side of the chimney, can be removed to load or unload fuel assemblies or experimental devices between the pool and the core. The water of the primary circuit flows from the bottom to the top of the chimney, passing between the plates of the fuel assemblies, at a rate of 50 m^3/h. It is cooled through the use of two heat exchangers from the secondary loop. At the nominal power, the primary water inlet and outlet temperatures are typically at 35 and 45 °C. At low power, i.e. below 50 kW, the reactor can be operated in natural convection.

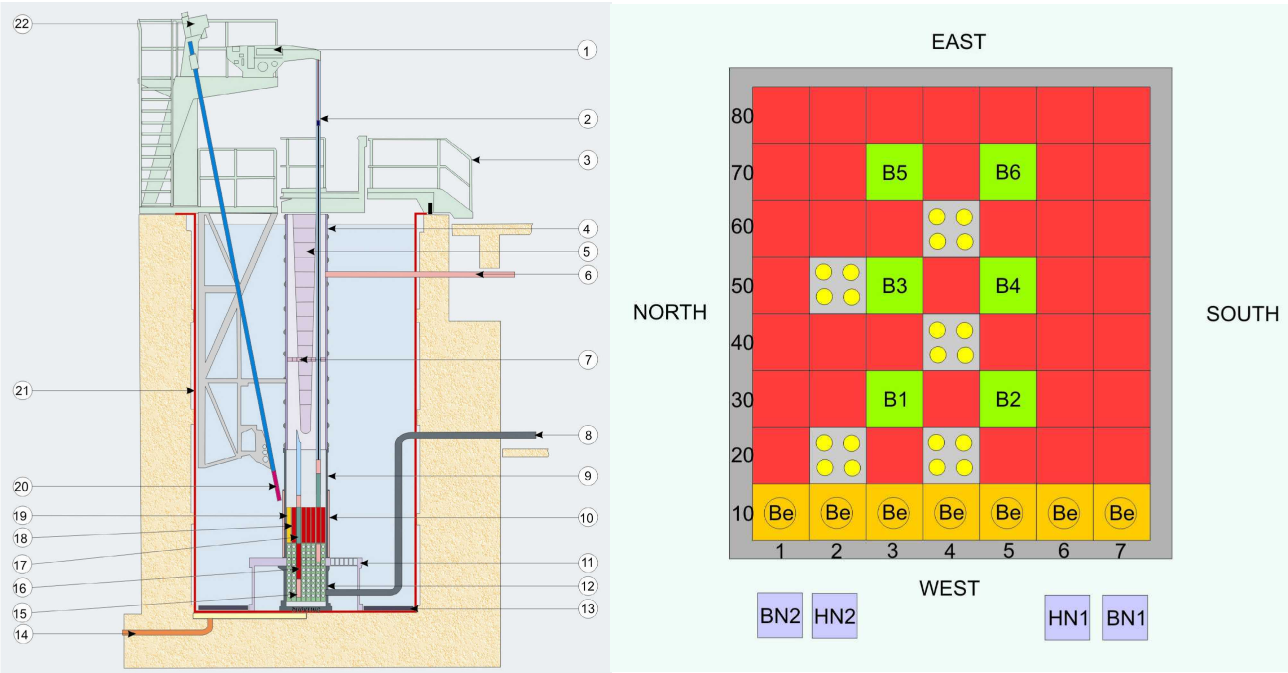

Fig 1. Schematic of the ISIS reactor pool (a – left hand side) and core (b – right hand side)

Figure 2-a shows a photo of the top of pool in the reactor hall, during the reactor presentation to students. The vertical metallic tubes in the middle of the picture are the mechanisms of the control rod. Figure 2-b shows the inside of the control room where the parameters of the reactor can be followed on a supervision screen in front of the participants.

Fig 2. Photos of: a - Reactor hall during ISIS presentation to the trainees, b- Control room

For the E&T, supervision software has been specifically developed and the logic of the safety system, the control system hardware, the ergonomics of the control board and control room were adapted to this specific activity. For example, the logic of the safety system was modified to enable the individual drop of each rod during standard reactor operation, and a specific operation mode was created for E&T activities, with a power limit fixed to 50 kW allowing the reactor operation in natural convection.

Figure 3 shows the information displayed by the supervision system that extract the signals measured during reactor operation. For each experiment, the parameters to be displayed are chosen by the instructor: the power, the core temperature and the position of the rod used to control the reactor for the study of the temperature effect.

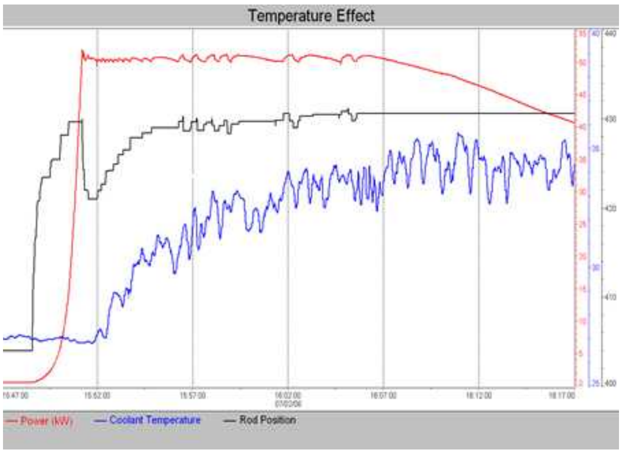

Fig 3. Supervision screen during the study of the temperature effect.

3. Curricula including training course on ISIS

Since 1956, INSTN has always promoted the use of laboratory work and training courses carried out on nuclear facilities in order complete theoretical courses. It was established that from a pedagogical point of view training courses on nuclear facilities and on nuclear reactors in particular was needed to ensure a practical and comprehensive understanding of the reactor principle and operation. Moreover, empathies being given to the impact of each operation and effect on the safety and security of the reactor design and operation, the training courses enhance the background of the trainees in nuclear safety. Thus, whenever it is needed training courses on ISIS reactor are integrated in E&T programs from INSTN.
INSTN is involved both in academic degree programmes and continuing education courses for professionals.

Concerning the academic degree, training courses on ISIS reactors are addressed to students and engineers from different institutions at a national and international level. This includes training courses carried out in the frame of:

- an international master in Nuclear Energy which is organised at INSTN in collaboration with other universities and engineer schools [5],
- a one year specialisation course in Nuclear Engineering which was developed by the INSTN in 1956 and contributed to the qualification of up to 140 engineers every year since this date [6],
- nuclear engineering modules of various master and engineer degrees in which the INSTN is involved,

- a collaboration agreement between Sweden and France that ensure the financial support for the organisation of up to 12 training sessions (2,5 days) on ISIS reactor for students from Swedish universities (Chalmers University of Technology, KTH Royal Institute of Technology, Uppsala University).

Concerning the continuing education for professionals, training courses on ISIS reactors are addressed to a very wide public including researchers, engineers and technicians. This includes training courses carried out in the frame of:

- a 8 weeks course which is compulsory in the qualification process of the operators of the French research reactors,
- different courses (taught in English or French) organised on a regular basis (at least once a year) and related to the principle, the operation, the safety and the neutronics of nuclear reactors,
- different courses organised by INSTN to respond to the specific need of the nuclear industry and nuclear programs, which includes courses for the personal of the French regulator body, for young engineers from the Italian company ENEL, for project managers of the Vietnamese company EVN (Electricity of Vietnam), or for teachers and professors from several Polish Universities (training of the trainees).

Depending on the pedagogic and qualification goals, the trainees follow different training programs (3 to 24 hours) on ISIS reactor that can be completed at INSTN by training courses carried out using other tools such as software applications (APOLLO, FLICA, TRIPOLI, MCNP, …) and reactor simulators (normal and accidental PWR operation). Two examples of E&T program using ISIS reactor are detailed bellow.

The first example is the 2,5 day training course on ISIS reactor organised for the Swedish universities. For this program, all the theoretical courses on the reactor principle and neutron kinetics are ensured by the universities prior the venue of the students on ISIS reactor. The content of the training course on ISIS reactor is as follow:

- 1st ½ day: presentation of ISIS and OSIRIS reactor, presentation of the content of the course, visit of the facility (the 2 reactors and the hot cells),
- 2nd ½ day: survey of the core reactivity during fuel loading (mix of fresh and burned fuel), observation of the loading process, approach to criticality for the determination of the critical configuration of the rods,
- 3rd ½ day: reactor start up and stabilisation at low power (no temperature effect), study of the change in core reactivity when removing aluminium devices from the core (change in the moderation factor), drawing of rod calibration curve (measurement of the doubling time),
- 4th ½ day: evaluation of the global worth of a rod (rod drop technique), study of the shadow effect, study of the temperature effect (Doppler and dilatation, self-stabilisation), determination on the temperature coefficient,
- 5th ½ day: study of the role of precursors in power stabilization (during a fast transient in reactivity), operation of the neutron detection systems of the reactor (signal, operating range, use for the reactor control and for safety system including reactor SCRAM).

This intensive training course gives a very good overview of the reactor operation and its practical and theoretical aspects: neutron and precursor kinetics, sub- and over-moderated regime, neutron distribution in the core, temperature feedback effect, etc. In each experiment, emphasis is given to the safety of the operation, by conducting a practical safety analysis of what is carried out on the reactor, both in normal and incidental condition.

The second example is the 8 week course which is compulsory in the qualification process of the operators of the French research reactors. This training program and the overall qualification process are in good accordance with the Safety guide NS-G-4.5 from IAEA, which describes the good practice in the recruitment, the training and the qualification of the personal of research reactors. Thus, along a whole qualification process that has duration of about one year, the trainees spend 8 weeks at INSTN to follow theoretical and practical courses on nuclear physics, reactor physics, neutronics, thermo hydraulics, safety and reactor operation. Examination is conducted both on the theoretical and practical aspects of the program. For this 8 week course, in addition to 2½ day program described above, the course also contains:

- the study of the neutron detection system, including their setting (bias voltage, discrimination level, calibration factor) and the follow up of the detector characteristics (impact of detector ageing on the signal and settings),
- radiation protection applied to reactor operation including neutron, beta and gamma dose rate measurements on the facility, as well as the measurement of the neutron flux by the analysis of activated samples,
- a sequence during which the trainee operates ISIS reactor under the supervision of the normal operating staff.

For the later one, the trainee has to learn some basic knowledge (including operating procedures) on ISIS reactor operation. He follows the operation of the reactor by an regular operator or another trainee, makes all the calculations necessary to operate the reactor (position of a rod to obtain a doubling time of 30 s, for example) and finally operate the reactor. The operating sequence includes for example : the reactor start up, the switch from the low level of power neutron detection systems to the high level ones, the reactor power stabilisation at 500 W, the search for another critical configuration of the rods by inserting one rod and compensating it by the extracting another one. During this sequence, the instructor from INSTN checks the trainee’s knowledge and skills to operate the reactor, including its response to stress. This first experience in the operation of a reactor is an important step in the qualification process of the future operator who is going to go through on the job training on its own facility for typically six to nine months before being licensed.

All the experiments carried out on the ISIS research reactor focus on the practical aspects of reactor design, principle and operation. Emphasis is given to the safety aspects both in normal and incidental conditions. The feedback from the participants shows that practical exercises, as well as hands on reactor operation, are very efficient in going deep inside the understanding of the theoretical courses on reactor physics. Indeed, training courses on a real nuclear facility is the only way participants can approach and understand how different taught subjects (reactor design, principle, operation, safety, radiation protection …) are taken into account to ensure the safe operation of a nuclear facility. The feedback from the trainee's, even years after they went through training courses on a research reactor, also shows that the impact of such course ensures comprehensive, and long standing, understanding of the reactor principle and operation that cannot be gained only with theoretical courses associated with the use of simulators.

Thus the INSTN is continuously promoting the use of the training courses on ISIS reactor in its E&T programs as they appear to be a very powerful tool for the development of the human resources needed by the nuclear industry and the nuclear programs.

4. Internet Reactor Laboratory

At an international level, a small number of research reactors are available for nuclear education programmes and human resource development. Thus, since the ISIS reactor has been specifically dedicated for education and training, CEA is promoting the use of the reactor at an international level. This is done in the frame of bilateral agreements, specific contracts or through the international courses that are organised by the INSTN.

When the supervision system of ISIS reactor was developed in 2003, the specifications were established taking into account remote access and data transmission. Nevertheless for pedagogical reasons, in-reactor training courses where promoted up to now by the INSTN. After the experience of "virtual reactor laboratory," which linked the PULSTAR research reactor at North Carolina State University with the Jordan University of Science and Technology (JUST) as a guest institution [7] and the demand for Internet Reactor Laboratories (IRL) at an international level, CEA decided to develop the remote access to the training courses carried out on the ISIS reactor.

Keeping in mind that IRL cannot replace real hands on a research reactor, IRL can be seen as a cost-effective way to expand the nuclear education for groups of students or trainees that would not normally have access to a research reactor during their education. It can also help states better train and evaluate their human capital needs for ensuing future (research or power) reactor projects.

With this limitations and expectations, CEA has decided to develop IRL broadcasted to guest institutions. Using a system based on Visio conference equipment, the following information can be sent from the ISIS reactor (host reactor) to the remote classroom at the guest institution(s):

(1) Power point presentations,

(2) Pages from the supervision system used by the operator to follow the state of the different systems of the reactor (control rods, neutron detection systems, cooling system, safety system…),

(3) Interactive white board were the lecturer can present and explain the experiments and results,

(4) Graphs from the supervision system showing the time evolution of selected parameters for each experiment,

(5) Tables of selected data recorded by the supervision system,

(6) Curves plotted using the recorded data after calculation,

(7) Movies to be shown to introduce or illustrate some experiments or phenomena,

(8) Video signals from four cameras looking at : the lecturer, the reactor hall, the core, the operator at control desk.

Out of this information, according to the pedagogic needs during the training courses, the lecturer on the ISIS will choose to broadcast the relevant information at each stage of the course. By interacting through video conference, the remote classroom will also be able to ask for the display of particular information. At the guest institution, the information will be displayed on two screens, one dedicated to the information selected out of (1) to (7) and the other one dedicated to the video signal selected out of the camera signals (8). Concerning the interaction with and the feedback from the remote classroom, at least one camera will be installed in the remote classroom and its signal will be sent to the ISIS control room to be visible par the lecturer and the operators.

On the 18th of September 2013 a demonstration of the potentiality of the IRL broadcasted from ISIS reactor was carried out in the frame of the side events of the IAEA General Conference. This demonstration was carried out with standard Visio-conference equipment with some limitation according to the final system that will be implemented for the IRL. Nevertheless, the demonstration was used to show the reactor start up, stabilisation at 50 W, increase of the power up to 50 kW to look at the temperature feedback effect and finally reactor SCRAM. The following information were broadcasted: Powerpoint presentation, graphs from the supervision system showing the time evolution of selected parameters and video signal from one underwater camera looking at the core and one movable camera placed in the control room. A very positive feedback was obtained for this first broadcasted reactor operation. Following this demonstration, the full system for IRL will be implemented in the next months and the first IRL are expected to be broadcasted in the first quarter of 2014.

5. Conclusion

Since 1956, the National Institute for Nuclear Science and Technology provides to students, engineers and researchers a high level of scientific and technological qualification in nuclear reactor theory and operation. The adopted strategy is to complete theoretical courses by training courses on training reactors. A large set of training courses have been developed on ISIS research reactor in the frame of the education and training programmes from the INSTN. The experience gained shows that such training courses bring tremendous benefits for all trainees since they ensure a practical and comprehensive understanding of the reactor physics, design and operation. With this feedback, the implementation of the Internet Reactor Laboratory, which will be operational in 2014, appears to be a powerful tool, complementary to in reactor training courses, for the development of the human resources needed by the nuclear industry and the nuclear programs.

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