MEETING REPORT

IAEA Technical Meeting
on
Use of Nuclear Facilities and Simulators as Effective Tools for Education and Preserving Knowledge

21-24 June 2010

Ljubljana, Slovenia

Table of Contents

1. Background

The important role which the International Atomic Energy Agency (IAEA) plays in assisting the Member States in the preservation and enhancement of nuclear knowledge and in facilitating international collaboration in this area has been recognized by the General Conference of the IAEA in resolutions GC(46)/RES/11B, GC(47)/RES/10B, GC(48)/RES/13, GC(50)/RES/13 and GC(51)/12 requesting the IAEA to assist the Member States in their efforts to ensure the preservation of knowledge in nuclear science and technology for peaceful purposes, which is a necessary prerequisite for succession planning, in particular through the networking and knowledge sharing among Member States and their institutions.

More than 50 Member States have recently approached the IAEA expressing interest in launching a nuclear power programme. In all cases the development of human resources capable of supporting the implementation of these programmes has been identified as one of the main challenges. Additionally, many of the 30 Member States that already have nuclear power programmes are either expanding or considering the expansion of their programmes. For many of them this comes at the same time as there is a need to replace the generation of workers that commissioned nuclear power plants (NPP) now in operation.

Given these needs, the education, recruitment, selection, training, qualification and retention of human resources to support the introduction and expansion of nuclear power programmes has been a matter of concern for many national governments and has attracted a great deal of attention and support from industry and international organizations. The decline in the number of young people studying nuclear sciences and a growing number of universities giving up or strongly limiting their nuclear education programmes have given rise to new initiatives for networking educational institutions, universities and industry training centres. New national and international "platforms" for sharing knowledge and expertise in nuclear education and training (WNU, ANENT, ENEN, ANSN, UNENE and others) have been established and have become the drivers for renewed interest in nuclear education.

Knowledge preservation is a key element of capacity building in countries with NPPs as well as those that are on the verge of developing a nuclear programme. Some of the key tools for national capacity building through nuclear education are simulators, which are considered as effective tools for nuclear education.

Over the past years, the IAEA has been working with universities to address future workforce demand developments and the quality and quantity of nuclear education. The coordinated efforts with Member State institutions led to the establishment of Networks for Education in Nuclear Technology (NENT) and a related web-based cyber platform.

The next step in the IAEA's activity is to share experiences and good practices on the use of simulators for nuclear education and to integrate some of the key computer-based simulators in the NENT cyber platform to enable wider dissemination of these tools to our Member States.

2. Objectives

The objective of this Technical Meeting was to provide participants with a forum to review and discuss the currently available nuclear power simulators for education and their integration in the Agency Network for Education in Nuclear Technology (A-NENT) Cyber Platform, in particular:

1. To share experiences and good practices on the use of simulators for nuclear education and knowledge preservation with emphasis on desktop simulators for various aspects of nuclear technology.
2. To identify educational simulators for the purpose of their integration in the Agency Network for Education in Nuclear Technology (A-NENT) Cyber Platform and make them available to A-NENT participants and to discuss and plan further practical arrangements needed to accomplish this task.
3. To explore the use of Internet Reactor Laboratory for supporting nuclear science and engineering education in developing countries.

List of participants of the technical meeting is given in Annex 1 and list of presentations is given in Annex 2.

3. Brief Description of Presentations by Participants

3.1 Presentation by Andrey Pryakhin

In the introductory presentation, Mr Pryakhin explained the objectives of the IAEA meeting as described above. He also explained the agenda and expected deliverables of the meeting.

In the ensuing presentation, Mr Pryakhin covered the following topics:

- IAEA activities related to nuclear education program – cyber learning model
- Educational networks created through IAEA initiative

IAEA Activities on Cyber Learning Nuclear Education

The core tool to support cyber nuclear education is a cyber learning portal, which consists of several cyber learning spaces.

The cyber learning portal consists of: Classroom, Teacher's room, Library and Social networking space.

Classroom is used by the students and it supports on-line tutoring, discussions and material exchange. It also supports real-time web-casting and video conferencing. Multimedia training courses along with assignments are distributed to the students for self-learning. Examinations/certification are also done in the classroom space.

Teacher's room consists of the faculty space, monitoring & control functions and teaching resources. Faculty space has roster of teachers and curricula in various subjects such as energy planning, nuclear power engineering, etc. Monitoring & control functions include course creation & approval, conducting tests, grading, etc. Resource space contains all on-line resources such as text books, country reports, nuclear knowledge indicators, etc.

The next part of cyber learning portal – Library – consists of catalogue of resources and knowledge retrieval tools, such as INIS, NuArch, etc. The Library in itself does not store any resource in most of the cases; however, it searches for a specific topic/subject and directs the user to the respective on-line resource – handbooks, portals, etc. - anywhere in the cyber-space.

The Social networking space is used to popularize the nuclear technology and to enable dialogue among various stakeholders in advancement of Nuclear Technology development: students, teachers, industry, utilities etc. Blogs, Twitter, IAEA facebook, and others can be used for this purpose.

Educational Network

Educational networks, being created under the initiative of IAEA, have the objective, "to provide a forum to exchange the policy and strategies for nuclear education and training and to facilitate the regional and interregional cooperation to share educational experiences and resources". Foremost among these networks is A-NENT (Asia Network for Education in Nuclear Technology). It was established by some Member States in the Asian region and the IAEA in 2004. It has 16 member countries in Asia-Pacific region, and some collaborating organisations. The system is currently hosted in Republic of Korea. A-NENT implements a 4x4 matrix cyber learning model. There are 4 roles of users – learners, lecturers, course managers and general managers – each of whom is associated with 4 processes, i.e. course availability, course registration, learning and post-learning. The targeted knowledge areas of cyber-learning are:

Nuclear Engineering, Nuclear Medicine, Energy Planning and Nuclear Knowledge Management. As part of the A-NENT, a cyber learning hub is being created recently in Khalifa University of Science, Technology and Research (KUSTAR), United Arab Emirates (UAE).

Based on the success of A-NENT, similar networks are being proposed in Latin America, North America, Africa and Europe.

3.2 Presentation by Ayman Hawari

Mr Hawari presented the 'Internet Research Laboratory' of North Carolina State University (NCSU), which has a 1 MW pool-type research reactor in-campus.

One of the objectives of the research reactor was to provide a hands-on understanding of the physics and operations of nuclear reactors to the nuclear engineers. The university offers academic courses in support of the Nuclear Engineering and conducts a 2-semester reactor operator training sequence. As part of the course, students can monitor the reactor operation from the control room of the reactor, but only the licensed operator is allowed to operate the reactor.

Recognizing that the direct monitoring of a reactor in operation would benefit the nuclear engineering students in better understanding the physics, it was decided to setup a facility by which students from remote sites can also monitor the reactor operation, just like on-compus students.

This facility, called Internet Research Laboratory, consists of a RTP Corp Hybrid control system, a control computer and a video conferencing system. RTP Corp system acquires data from the reactor in parallel to the control room console and passes on these to the control computer, which sends these data over Internet to the remote computer. The remote computer has a soft-panel that replicates the reactor control console and students at remote site are able to watch changes in the reactor parameters on the soft-panel as on the actual control console. In addition, using the video conferencing facility using the camera placed in the control room, students at remote site can watch the reactor operation on the local monitor and control the camera to focus/zoom on a particular display on the control console.

The video conferencing facility also allows the teacher in control room to explain specific steps of the operation to the remote students, who can pose questions to their local teacher, who in turn can communicate to the reactor operator. It may be noted that the remote site can only monitor the reactor operation; it cannot control the reactor.

Typical experiments conducted are: reactor startup, including reach of criticality, control rod worth measurement, power coefficient measurement, etc. This 'Internet Research Laboratory' was successfully demonstrated by NCSU with remote sites at University of Tennessee and Georgia Institute of Technology. The underlying infrastructure - internet and video conferencing – allows this concept to be extended to connect any university anywhere in the world provided the nuclear safety and security concerns are appropriately addressed. Currently, NCSU and Jordan University of Science and Technology (JUST) are working on a program to use this facility to connect NCSU to JUST.

To summarise, 'Internet Research Laboratory' at NCSU has established the following:

- The real-time use of a research nuclear reactor in distance learning exercises is feasible

- The approach is less demanding both physically and economically than traditional on-site learning
- It can address the needs of large numbers of trainees without leaving the home base

3.3 Presentation by Konstantin Peradze

Mr. Peradze described the current status of Ignalina NPP, Unit#1 and Unit#2 of which are being decommissioned. It is expected that Lithuania would construct new NPP's in a few years. In this context, the vital concern is: does the knowledge acquired in so many years of operation of the Ignalina NPP's be lost? The knowledge can be preserved, to some extent by a systematic approach, which involves: a) identification of critical knowledge; b) archiving of the critical knowledge in the form a report generated through interviews with personnel, who have the critical knowledge.

It was also explained that the full scope simulator of Ignalina NPP is used to provide periodic training to control room personnel and to provide demonstration exercises to students of two Lithuanian Universities. Although it is desirable to provide similar opportunity to students from other universities, there are problems because: a) the universities are situated far away; b) it is not possible to accommodate large group of students; c) there are funding difficulties in carrying out these tasks.

3.4 Presentation by RM Suresh babu

Mr. Suresh babu presented the following topics:

- Implementation models for educational simulators
- Indian experience in development of simulators

There are two implementation models that can be adopted for educational simulators: e-learning model and cyber-learning model.

E-learning model uses desktop simulators, but it is confined to an institute or research center. As a first step, this model identifies specific topics in the subjects being taught as part of the curriculum e.g. reactor control, xenon oscillations, etc. Then, it makes specific e-packages (automatic execution of desktop simulator software) for each of the above topics, with facility to change certain important parameters (e.g. burnup, core life,..). Students can execute these e-packages and can experiment with various parameters as part of e-learning.

Cyber-learning is also based on desktop simulators, but the students and simulators/e-tools are spread across a university, country or across the globe. It uses client-server model: client machine is used by the students and server machine runs the simulators or e-tools. Server machines have all facilities/features of the e-learning model; but, in addition, have network capability and features to implement client-server model. Client machines are able to access any of the servers across the cyber space and execute a specific topic. The inputs and feedbacks are available in realistic time frame, provided the internet supports sufficient bandwidth or dedicated leased networks are used.

The presentation also covered various types of simulators developed in India: full scope simulators for various plants for training of reactor operators; fuel-handling system simulators for training on refueling operations; engineering simulators for testing a number of indigenously developed control systems. These systems are big and complex; however, these can be scaled down to desktop simulators so that these can be used in e-learning or cyber-learning models described above.

3.5 Presentation by Viktor Bernath

Mr. Viktor Bernath distributed a brochure on Paks NPP full scale simulator, Hungary. It describes how the simulator was developed in a systematic manner, how training on the simulator is imparted to the operating personnel, how the simulator was updated and improved on the basis of feedbacks from the operating plant.

3.6 Presentation by Evgeniy Chernov

Mr. Chernov presented application of the following simulators for education:

- WWER-1000 Reactor Simulator
- WWER-1000 Reactor Department Multi-Functional Analyzer (MFA-RD)

WWER-1000 Reactor Simulator is a part of IAEA collection of PC-Based Simulators for Education. It provides insight of the reactor design as well as a clear understanding of the operational characteristics of WWER-1000 reactor. It can be used as an introductory educational tool as well as a tool for the development of nuclear engineering courses; however, it cannot be used for safety analysis. It models all important systems of primary and secondary circuits as well as the control system. The simulation can be done with different core loadings. Scope of simulation covers normal operational conditions, including reactor startup, working at rated power level and reactor shutdown; abnormal operational conditions like reactor cooling pump trip, valves closure etc.; and restoration of reactor power after rectification of malfunction. The core simulation includes: transients on prompt and delayed neutrons, Xenon radial and axial power distribution oscillations, Samarium poisoning, Fuel burnup (without core refueling) and residual heat. The training task describes: objectives of the task, sequence of actions to be performed by simulator user, and reference to the corresponded simulator display pages outputs and controls. The simulator offers convenient operator interface with: display screens that show reactor state, important plant parameters, axial and radial distribution; and controls for control rod operation, equipment operation and automatic controller operation.

MFA-FD has resulted from a further refinement of WWER-1000 reactor simulator, and it can be used as reactor steady-state and transients analysis tool. It is benchmarked against WWER-1000 experimental and calculated data and is certified for WWER-1000 type reactors computations by the State Atomic Inspection of Russia. It is specifically adapted to illustrate numerous problems in the field of neutron physics, thermal-hydraulics and control of nuclear power plants. It allows arbitrary core loading configuration and control rod locations in the core. MEPhI effectively uses MFA-RD in two lectures courses and related laboratory works:

- Lecture course - “Automatic control in Nuclear Power Plants” and Labs “Control and Protection Systems”
- Lecture course - “Numerical modeling of physical processes in equipment of NPP” and Labs “Control and Safety of operation of NPP”

In May 2010, IAEA organized and sponsored a Workshop in Belorussian State University in which the above mentioned courses were conducted by MEPhI. Based on its success, Belorussia State University now plans to introduce these courses, with use of computer simulating system, in their educational programme.

3.7 Presentation by Dr Negrenti

The recent reorganisation at ENEA (now redefined as the National Agency for Advanced Technologies Energy and the Economically Sustainable Development) has included the creation of a relevant Technical Unit (‘FISST’) dedicated to research reactors and fission technologies, and located at Casaccia Research Centre near Rome.

Within this macro unit a Laboratory has been set up aiming at the realisation of Engineering Simulators for the power plants expected to be built in Italy in the next 10 years (most probably EPR and AP1000).

Two nuclear facilities are available at Casaccia Centre and managed by the Fission technologies Unit: TRIGA thermal reactor and TAPIRO fast neutrons reactor. Such plants have various technological applications and are also the subject of training efforts in cooperation with Italian Universities.

The Engineering Simulation Lab is currently reviewing the international state of the art in the field of NPP simulators, widening the scope of this analysis also to Full Scale Simulators and Education Simulators. In facts an accurate knowledge of all the types of NPP simulators is a pre-requisite for the appropriate definition of the functionalities and technical characteristics of Engineering Simulators. Moreover a specific activity is being developed for the identification of evolutionary contents of future engineering and full scale simulators (e.g. the possibility of analyzing alternative operation scenarios in the unlucky case of a severe accidents affecting the environment and the population around the NPP, thanks to the nowadays availability of simulation systems of very high speed having significant ‘time margins’ vs the real time calculation needs). Potential partners are being identified and contacted for creating teams capable of starting the development of enhanced simulators in a short term. Meanwhile the Lab will certainly make use of Education simulators (such as those proposed by IAEA) for multiple reasons including cooperation between ENEA and Universities committed in the Nuclear field and the aggregation and ‘refreshing’ of nuclear competences under-exploited and-or re-oriented along the recent twenty years of ‘no-nuclear’ energy policy in Italy.

3.8 Presentation by Tomaž Skobe

Mr. Tomaž Skobe presented Multi-functional simulator (MFS), installed at Nuclear Training Centre (NTC), Ljubljana, Slovenia. It is primarily meant for providing basic training to the operating personnel of Krško NPP. The basic training has two phases. Phase-1 covers the theory of: reactor physics, thermo-dynamics, instrumentation and control, etc. and laboratory exercises of radioactivity detection and research reactor TRIGA operation. Phase-2 covers familiarization with various plant systems and operating procedures such as general operational procedures (GOP), abnormal operational procedures (AOP), emergency operational procedures (EOP), etc. MFS is also used for re-training of operators and training of non-operators.

3.9 Presentation by Igor Fifnja

Mr Igor Fifnja presented the full scope training simulator of Krško NPP. The simulator consists of replicated main control room (MCR) - all cabinets with active controls and indications - process information system, local shutdown panels, and complete set of communication devices. It models 80 systems including reactor, feedwater system, turbine, etc. This simulator provides training and re-training to the operator personnel includng the licensed operators and field operators. The training consists of three phases. Phase 1 covers the basic simulator principles and the analyses of plant transients. Phase 2 covers familiarization with main control panel and operation of components and systems. Phase 3 covers normal operation, abnormal operation and emergency operation. Simulator was effectively utilized also for: emergency organization exercises, just-in-time training prior to important plant activities, development of operating procedures, testing of plant modifications before implementation in the plant.

4 Feedbacks from NTC Participants

The participants from Nuclear Training Centre (NTC) felt that the meeting exposed them to many aspects of simulators and it was a good starting point for their future works.

Mr Pryakhin's presentation on A-NENT provided guidance about locating information regarding instructor's role on training students for NPP. It also provided information for different groups in one place, i.e. E-learning portal based on sharing and learning information.

Mr. Hawari presented interesting ideas on how to conduct distance education using internet and video conferencing. The most interesting part is that it is feasible to use a research nuclear reactor in distance learning exercises with direct feedback from students at remote universities.

Mr Peradze provided in his presentation more questions than answers based on the current condition of Ignalina NPP and pointed out that decommissioning process can lead to loose of operational knowledge for new NPP's in Lithuania.

Mr Sureshbabu stressed the approach of models E-learning model and Cyber-learning model and gave his perspective from Indian experience.

Mr. Chernov presented Russian version of WWER simulators, but it would be interesting to know how these types of reactor compare with American or European type of NPP's, which are proposed for Slovenia.

Mr Negrenti presented two types of research reactors for educational purposes in Italy; one is similar to the TRIGA reactor.

5 Conclusions and Recommendations

5.1 Use of Nuclear Facilities for Education

The 'Internet Research Laboratory' of North Carolina State University, USA is a good example of how research reactors can be used to educate students of nuclear engineering at remote sites, even across the globe. This is a cost effective method of cyber-learning, in which the students and the teachers can interact from their own home campus with no need to move from one place to another. Member countries can explore the possibility of collaboration with NCSU or may even emulate this example by providing facility to monitor operation of their research reactors to the educational institutes in their countries.

IAEA can facilitate those activities – such as workshops – with the participation of member countries for effective implementation of this concept.

It is recommended to implement IRL experience in the Nuclear Networks for Education and work in co-operation with NCSU for this purpose.

5.2 Use of Simulators for Education and Knowledge Preservation

WWER-1000 Simulator, from Moscow Engineering and Physics Institute (MEPhI) is considered as a good example of computer tools that allow the understanding of basics of WWER-1000 operation and PWR concept as well.

The desktop simulators distributed by IAEA can be effectively used in training of students in Nuclear technology; as presented by MEPhI. Member countries should be encouraged to use these simulators and further cooperation among member countries in this direction should be accelerated.

Member countries may be urged to upgrade educational programmes with practical training using existing training tools and facilities including engineering simulators.

Analysis of decommissioning projects at Ignalina NPP has shown that full scale simulators can be used for knowledge preservation. Member countries, which have started decommissioning processes, should examine the existing training tools and facilities (full scope simulators and engineering simulators) with the purpose to use it for nuclear education and knowledge preservation.

It is recommended to consider the opportunity to upgrade the current WWER-1000 Simulator to the current level of compatibility with Windows OS and to update the training contents as well.

It is recommended also to consider the opportunity to include WWER-1000 Simulator in the IAEA cyber learning platform for educational purpose.

5.3 Networks for Nuclear Education

IAEA can establish mechanisms, such as organization of workshops, for effective exchange of information between nuclear engineering educational organizations.

Annex 1

List of Participants

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Annex 2

List of Presentations

No.	Name and presentation title
1.	Mr Andrey Pryakhin IAEA Activities on Cyber Learning Program
2.	Mr Andrey Pryakhin Networking Nuclear Education
3.	Prof Ayman I. Hawari Internet Reactor Laboratory: A Remote Learning Modality for Illustrating the Physics of Nuclear Reactors
4.	Mr Konstantin Peradze Use of Ignalina NPP Training Facilities for Education and Knowledge Preservation
5.	Mr RM Suresh babu Simulators for Education in Nuclear Technology
6.	Mr Evgeniy Chernov Application of WWER-1000 Reactor Department Simulator for Education and Preserving Knowledge Purposes
7.	Dr. Ing. Emanuele Negrenti Simulators and Nuclear facilities for Education and Knowledge preservation
8.	Mr Tomaž Skobe Nuclear Training Centre : Multifunctional simulator (MFS)
9.	Mr Igor Fifnja Krško NPP : Utilization of simulator