# The Role of IAEA in Human Capacity Building
## *Active Learning and Training-by-Doing Education Programmes Based on the Basic Principle Reactor Simulators*

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**Abstract**

Within its Statue the International Atomic Energy Agency (IAEA) continuously adapts scope of activities in meeting the needs of its Member States (MSs). In the scope area of educating and training nuclear researchers, engineers and regulators world-wide, in 1997 the IAEA established a new core education and training programme toward more efficient human capacity building in MSs. This programme integrates theoretical teaching with active learning based on the basic principle reactor simulators. Operating on personal computers these software provide a thorough hands-on demonstration of the basic operational principles of various nuclear power plants by illustrating general concepts, and demonstrating fundamental safety processes in normal and transient/accident conditions. A combination of lectures on theoretical principles and technology specifics along with the ability to more methodically study through "experiencing" the actual physical behaviour of a nuclear power plant under various conditions has proved to be one of the most effective approaches in teaching the nuclear technology fundamentals. Through this education programme, delivered in training courses and workshops, the IAEA supports a technology tutoring to the newcomer nations and MSs pursuing and/or expanding their national nuclear power programmes. In this paper we present the structure of the training-by-doing approach based on the IAEA library of basic principle reactor simulators of various conventional and advanced reactor technologies. Such training is aimed at human capacity building in improving the knowledge-based skills on safety and safe operation of the nuclear power plants.

## 1. Introduction

A considerable improvement in retention of teaching and training material as well as better understanding of underlying concepts are shown to be achieved when using educational simulators. The so-called learning pyramid as shown in Fig. 1, partially based on Bloom's taxonomy of educational objectives, shows that by active learning about a particular phenomenon we enter the active learning zone and the retention increases significantly. Compared to only theoretical teaching (old-classroom teaching style) the knowledge gained through lectures retain at much lower percentage when compared to training by doing.

The IAEA's PC based basic principle nuclear power plant simulators aid in presenting to the trainees the complex system interactions within a nuclear power plant. A particular phenomenon when studied and then simulated with effective graphic user interfaces, reaches an active learning zone, ultimately increasing the retention rate. Also, the use of nuclear power plant simulators in general helps in education and training without posing any risk to plant equipment or personnel. In post-Fukushima era a major focus in training is on safety analysis and accidents development and mitigation actions. The repetition of scenarios as many times as necessary enables not only in familiarization of various safety features of a power plant, but also helps in giving broader overview of general safety characteristics of a particular type of nuclear power plant.

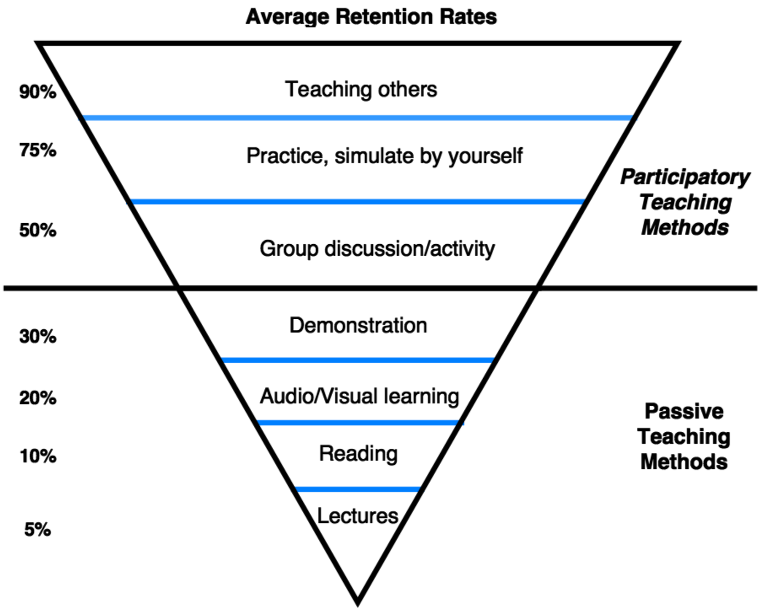



**Figure 1. Learning Pyramid:** ***Training Method vs Retention of Knowledge***

Since 1997 the IAEA maintains as one of its core activities the training courses based on reactor simulations to assist Member States in educating nuclear and regulatory professionals in the fundamental behaviour and operations of various types of reactors. The current suite of the IAEA PC based basic principle simulators includes the simulators for all water-cooled reactor technologies: pressurised water reactor (PWR), pressurised heavy water reactor (PHWR), boiling water reactor (BWR) and small modular reactor (the integral pressurised water reactor, iPWR). The IAEA maintains this variety of basic principles simulators that provide insight and understanding of the design, operational characteristics, key safety systems, and transient/accident behaviour of various types of reactors [1]. These IAEA simulators are available for free distributions to the interested Member States. Since its inception more than 700 software copies have been distributed; for example just in 2016 the IAEA has distributed 220 copies to 75 organizations in 36 Member States. Recently there has been an increasing interest in using these simulators in both developed and "newcomer" countries as they prepare to train a next generation of nuclear professionals.

## 2. The use of PC Based Basic Principle Simulators in Human Capacity Building for Safe Operation of NPPs

### 2.1 Overview of the IAEA Simulators

In this section we outline the structure of the training-by-doing teaching approach based on the IAEA suite of basic principle nuclear power plant simulators of various conventional and advanced reactor technologies, and how this approach is crucial in building human capacity with a better understanding of safety systems and safety related aspects in different types of technologies. The currently available IAEA PC based basic principle simulators are listed in Table 1.

**Table 1 IAEA's PC based basic principle educational and training simulators**

| Pressurized Water Reactor | Boiling Water Reactor | Pressurized Heavy Water Reactor | Small Modular Reactor |
|---|---|---|---|
| Conventional two loop PWR (PCTRAN) | Advanced BWR | Conventional PHWR | Integral Pressurized Water Reactor (iPWR) |
| Korean type PWR | Advanced Passive BWR | Advanced PHWR | |
| Russian type PWR | | | |
| Advanced Passive PWR | | | |

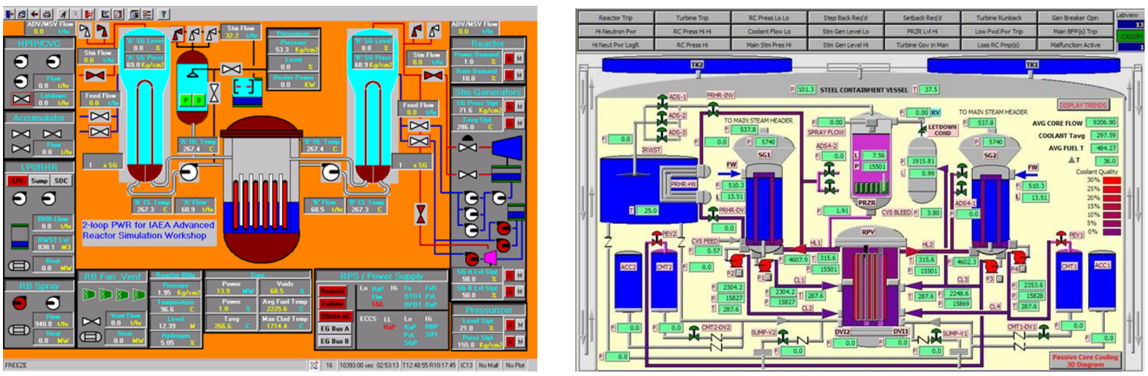
Developing, maintaining or increasing the fleet of nuclear power plants comes with its own challenges, and one of the major challenges is the development of human capacity. The training-by-doing approach developed by the IAEA using simulators emphasizes not only on operational characteristics of a nuclear power plant but also on its safe operation, and thus builds a strong foundation of safety principles at the early stages of the national nuclear power programme development. The simpler design of the basic principle simulators, as compared to full scope plant simulators, allows trainees to more quickly grasp on the fundamentals through learning-by-doing without missing details of complex nuclear technology processes. The developing countries which are in their first or second phase of nuclear power program development take benefit of such low cost but highly effective training. Developed countries, which have a well-established nuclear power programs, also benefit from this training course in order to fill in the generation gap, which is evidently challenging. These simulators prove to be an excellent tool to train the early career professionals faster and efficiently.

### 2.2 Training-by-Doing Approach for Human Capacity Building in Improving the Safe Operation of Nuclear Power Plants: *A Training Example*

***Training-by-Doing:*** The main training support function of a PC based educational simulator is to complement the engineering and full scope training simulators. Various plant abnormal transients/accidents/malfunctions can be demonstrated to the engineers, operators, and safety reviewers at a very early stage of the design of the plant. The simulators aid in the familiarization with the plant design, and evaluation of possible means of mitigating the accidents by allowing the user to learn such specifics by doing the analysis with the simulators. The training-by-doing approach has several benefits over conventional theoretical approach; the classroom knowledge becomes significantly efficient with early hands on training, the duration of the training course is shortened, the pace of the learning could be easily customized by adjusting the computer based training (CBT) even without an instructor. Additionally the new generations of engineers are familiar with the modern technologies and advancements of computer systems, that simulator based training-by-doing aligns well with the expectations on the efficient and effective means of training. . The simulator environment provides real plant situation and demands real time response from the users.

***Training Example:*** In training on the fundamentals of plant transients it is paramount to understand how each and every system in the overall plant behaves and corresponds. Such systemic response behaviour could be easily demonstrated with the help of the graphical user interface of the simulator. Figure 2 shows two examples:

- Figure 2(a) represents the graphical interface as seen on the personal computer using a transient analyser (PCTRAN) simulator, which is a two loop PWR. Here the complete primary and secondary system along with various safety systems provides a complete outline of major systems and components as present in a PWR.
- Figure 2 (b) shows the outline of an advanced passive PWR plant; when compared to Fig. 2(a), the passive safety features of the NPP could be seen clearly by the user. For example the Internal Residual Water Storage Tank (IRWST) is present in the advanced design and not in the conventional one.



(a) (b)

**Figure 2 Graphical User Interface of IAEA's Simulators: (a) PCTRAN; (b) Advanced Passive PWR (refer to Table 1)**

Here we show one illustrative example on training-by-doing with the goal to build an understanding of the fundamentals of a PWR plant response during a large break loss of coolant accident (LBLOCA). Using PCTRAN simulator all the major transient phenomena as well as the responses of emergency core cooling system could be easily and repeatedly simulated. Figure 3 shows the graphical representation of a pipe break during LBLOCA scenario. This visual easily points at the position of a break, if it is a cold leg LOCA or a hot leg LOCA (in this case it is a cold leg), with the flow coming out of the break in providing information about the size of the break. Monitoring various other parameters available on the screen during this scenario gives a solid understanding of the plant dynamics. The most important variables relevant to safety of the nuclear power plant could be continuously monitored in thus providing a broad view of safety features of this plant.

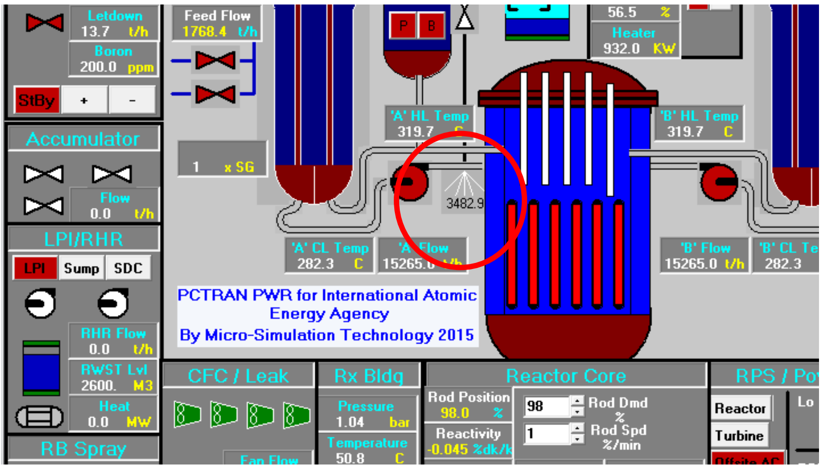



**Figure 3 Graphical Representation of a Pipe Break during LBLOCA in a PWR using PCTRAN Simulator (refer to Table 1)**

In this scenario, there is rapid depressurization (as shown in Figure 4), and the reactor trips due to low primary system pressure. This is a safety feature that stops the neutron chain reaction in order to avoid a progression of this accident towards its more severe development.

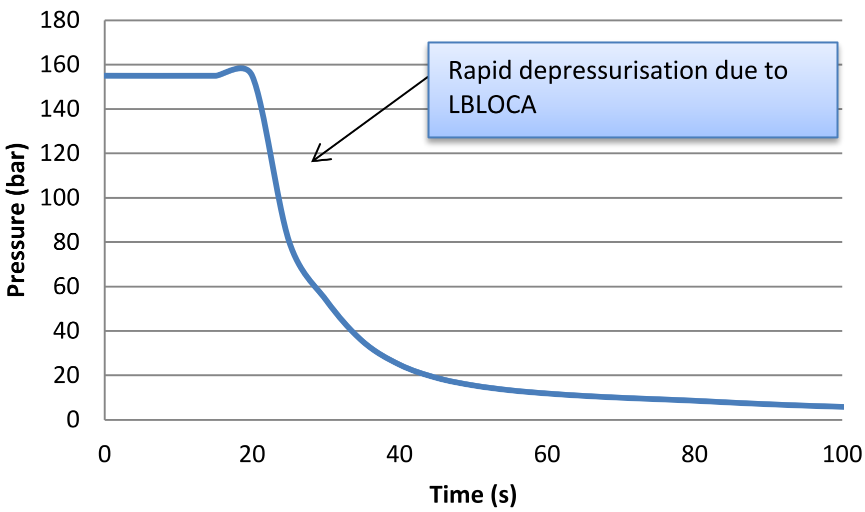
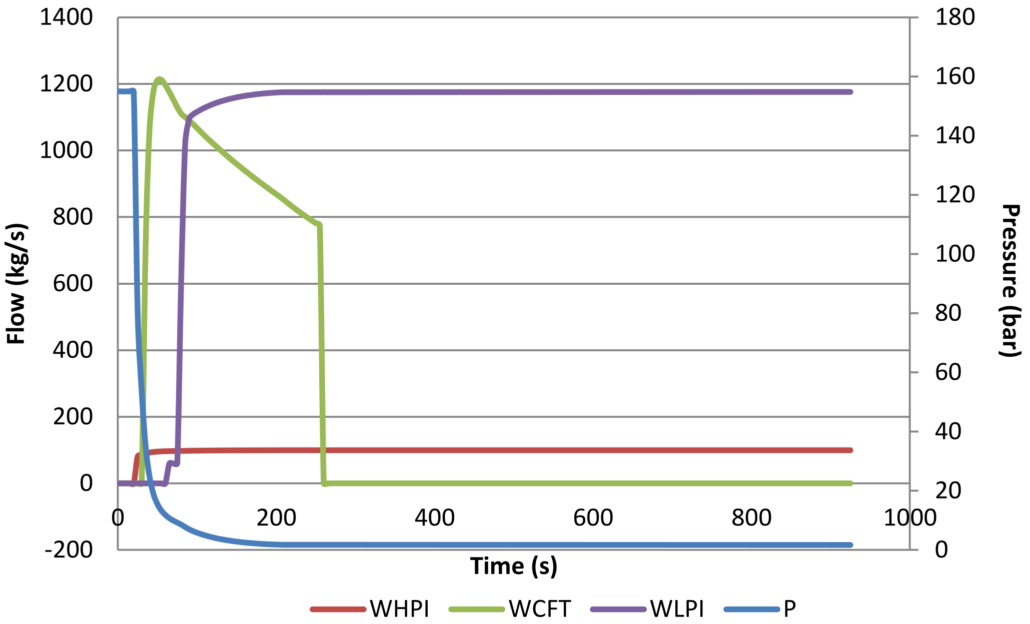



**Figure 4 Primary System Pressure vs Time during LBLOCA in a PWR using PCTRAN Simulator**

The working of emergency core cooling systems (ECCS) viz. high pressure injection (HPI) system, low pressure injection (LPI) system and accumulators, which are the safety systems are designed to work at different pressures and their actuation could be easily seen in the simulator both graphically and also by plotting the trends. Figure 4 shows the actuation of each of the systems with pressure, the flow of the system is measured along with the progression of the transient and it could be seen that the high pressure injection (WHPI) starts first but provides low flow, the accumulators (WCFT) start after the high pressure injection system, provide large amount of water to the core and then gradually the flow diminishes as the tanks become empty, finally reaching a value of zero. The low pressure injection (WLPI) flow is the one that maintains the long term cooling and has the maximum flow rate.




[WHPI: Flow, High pressure injection system; WCFT: Flow, Accumulators; WLPI: Flow, Low pressure injection system; P: Primary pressure]

**Figure 5 Emergency Core Cooling System's Response during LB LOCA in PWR using PCTRAN Simulator**

There are many other transients, accidents and normal operation scenarios that could be simulated using the IAEA's simulators being therefore helpful in teaching safety related aspects of various types of power plants. A comparison of safety features across different technologies provides deeper understanding of the underlying safety designs of each type of the plants.

## 3. Conclusions

The IAEA's PC based basic principle simulators are excellent tools for early phase training and education on operation and safety aspects of various nuclear power plant technologies. The user friendly graphical user interface provides means of intuitive learning. A series of display pages showing different plant views provides the complete system information at one place. The safety related concepts and phenomena could be easily explained with the simulators along with understanding of valuable technological differences in various designs. Simulators are one of the important tools for learning and also to stimulate interest in this technology amongst students and young professionals.

The IAEA provides regular regional, interregional and national training courses in different countries every year. The course approach is very practical as it is more cost-effective and efficient than alternative methods. One of the objectives of the program is to make sure that the newcomer countries, which have taken a decision to establish and expand their nuclear program, pursue this in a building their human capacity starting from learning the fundamentals of nuclear technologies. Reactor safety is one of the major concerns and the simulator program helps in teaching towards understanding of safety in very early phases of national power programme developments. Active learning and training-by-doing education programme is a valuable addition not only to countries pursuing nuclear energy programme development and deployment but also to countries with well-established nuclear programmes.

**References**

[1] IAEA, IAEA Collection of Basic Principle Simulators for Education, Nuclear Energy Nuclear Power webpage, https://www.iaea.org/NuclearPower/Simulators/.