FHS PERSONNEL TRAINING, EXAMINATION AND KNOWLEDGE EVALUATION – SIPEC PRO E-LEARNING INFORMATICS SYSTEM

IONUŢ DOBRIN, NICOLAE MARINESCU
Institute for Nuclear Research (RATEN ICN), Piteşti, Romania
e-mail: ionut.dobrin1990@yahoo.ro

Abstract

Fuel Handling System (FHS) is one of the most important systems in a CANDU Nuclear Power Plant, being used for on-power reactor refuelling. One of the RATEN ICN objectives is continuous learning, consolidating and maintaining the professional knowledge required to operate current equipment. To achieve this, at Out of Pile Testing Department was developed an informatics system called SIPEC Pro intended for the Fuel Handling System operation activities and exploitation implied personnel training, examination and knowledge evaluation. This interactive e-learning system allows an efficient knowledge accumulation regarding Fuel Handling System, all of its courses being sufficient for understanding treated subjects, thus reducing the so-called documentation time. Each course is composed of an introduction in subject of matter with additional explanations regarding CANDU reactors followed by the course main information, one chapter for conclusions, abbreviation and references. After the completion of course, one could evaluate its acquired knowledge by solving the interactive questionnaire. Newly hired personnel received at-work training through this programme, but also existing personnel had the opportunity to refresh the acquired knowledge during its work period in the Institute for Nuclear Research. Whole course package was a success, after its completion promising results being observed. Further it is desired to expand SIPEC Pro with courses regarding other CANDU reactor subjects of interest in addition to the Fuel Handling System.

Keywords: *Fuel Handling System, CANDU, SIPEC Pro, E-learning*

Introduction

E-Learning methods had an explosive development during the last decades and became one of the integrated components of educational systems in most companies, schools and universities. The term e-learning is associated to all the programs and materials distributed through any electronic method.

SIPEC Pro is a modern e-leaning system developed in Toolbook Instructor software which consists of several electronic books structured in chapters.

These electronic books (courses), fully developed in the Institute for Nuclear Research Pitesti, focus on CANDU Fuel Handling System. They are intended for professional knowledge development and evaluation of Fuel Handling System personnel involved in operation activities and exploitation of the test rig, so they can be able to test the CANDU Reactor Fuelling Machine (F/M) Head.

So far were created courses regarding the F/M Head and its components (Separators, Magazine, RAM and Snout Assembly), auxiliary F/M tools/devices (RAM Adaptor, FARE Tool, Channel Closure Plug, Shield Plug, Guide Sleeve and Insertion Tool) and nuclear fuel transfer equipment.

Toolbook instructor

SIPEC Pro was created in Toolbook Instructor 9.5, and one of its advantages is the ability to develop an interactive electronic course interface. Such an interface has navigation buttons (″forward″, ″backward″, ″menu″) and interactive questionnaires which specify the correct/ wrong answer.

Toolbook Instructor 9.5 consists of two operation levels. First level is called ″author level″ and this is the environment where an application is created and modified using different development tools (tool bars, templates, graphic elements catalogue and various colours). Also, at this level, the developer can create and modify objects and their properties, defining their appearance and behaviour.

The second level is called ″reader level″ and it's the environment where the created courses can be tested during development stage, but it is also the interface that is visible for all readers. Here, the users interact with created e-book, navigate to any page, can read texts and answer questions regarding the subject of the course.

Fuel Handling System

This system is one of the most important systems in a CANDU Nuclear Power Plant, its main advantages being the shut-down or on-power reactor refuelling achieved with the Fuelling Machine (F/M) Head [1].

The F/M Head is a mechanical robot controlled by a hydraulic driving which performs operations required in a complete refuelling cycle, but also different fuel channel interventions [2].

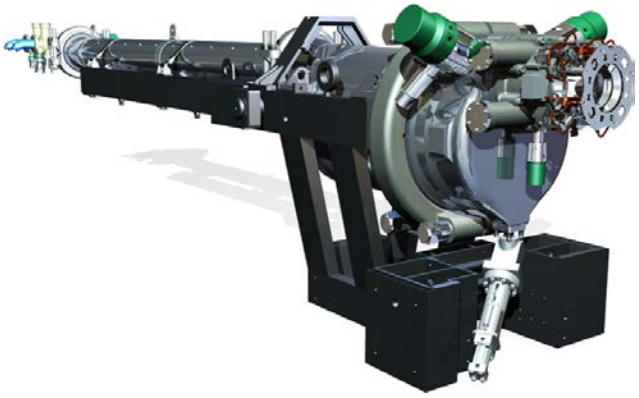


Fig. 1. Fuelling Machine Head – Autodesk Inventor rendered image

A normal refuelling cycle requires two F/M Heads pressure-tight connected to each end-fitting of the fuel channel, performing charging/discharging operations.

First of all, the upstream F/M Head takes the new nuclear fuel in its own magazine and transports it from the fuel port to the reactor. After positioning in front of the reactor, the F/M Head checks the correct alignment on the upstream end-fitting of the fuel channel, then proceeds the sealed coupling process. Next step is to open the fuel channel, which has an approximately 23kg/s heavy water flow at a pressure of 110 bar and a temperature of 307 °C, to transfer the new fuel bundles into the channel. Last operation performed by the upstream F/M Head is to pressure-tight close the fuel channel, leaving the reactor and heading to the maintenance room, where it stays in steady-state until the next fuel changing operation [3].

Simultaneous, at the downstream end-fitting of the same fuel channel, another F/M Head receive the spent nuclear fuel bundles in its own magazine according to the following operations similar to the ones executed by the upstream F/M Head. After positioning in front of the reactor, and completing the correct alignment process at the downstream end-fitting of the fuel channel, the F/M Head will couple itself on the fuel channel, opening it to receive the spent fuel. Afterwards, the F/M Head closes the fuel channel, leaving the reactor room and heading to the spent fuel port where it will transfer the whole fuel load. Finally, the F/M Head will move towards the maintenance room, where it will stay until the next fuel discharging operation.

During these operations, each F/M Head is transported with the carriage and suspension assembly which travels on the fuelling machine bridge, ensuring moving on all 3 coordinates axes. The Fuelling Machine Head is also provided with a cradle which bears the hydraulic oil and D_2O system, the manual magazine drive and counterweights.

The F/M Head is composed of four mechanisms, each serving a different purpose.

The Snout assembly is located in front of the Fuelling Machine and forms an extension of the pressurized F/M enclosure. This assembly main purpose is to lock and seal the F/M Head onto the fuel channel.

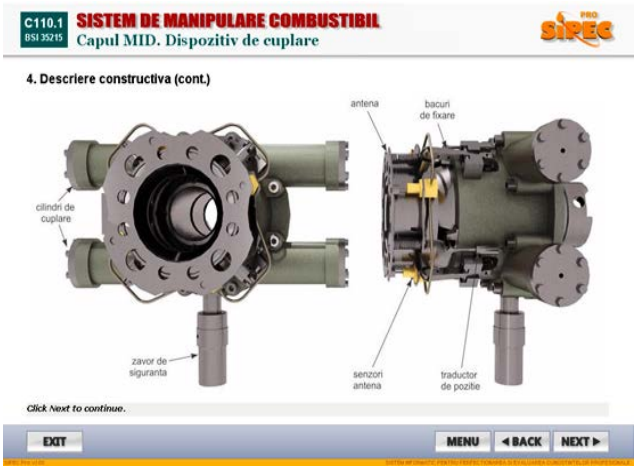


Fig. 2. F/M Head Snout assembly

coupling cylinders - cilindri de cuplare; snout emergency lock assembly - zavor de siguranta; antenna plate - antena; snout locking jaws - bacuri de fixare; antenna sensors - senzori antena; linear potentiometer - traductor pozitie

The F/M Magazine assembly is used to store and transport new fuel bundles that are to be inserted in the channel or spent fuel which were previously discharged from the channel. Additionally, the F/M Magazine contains tools and auxiliary devices used in a refuelling cycle or different fuel channel interventions.



Fig. 3. F/M Magazine assembly

magazine end cover - capac magazie; magazine Grayloc clamp - brida Grayloc magazie; RAM Grayloc clamp - brida Grayloc impingatori; rotary potentiometer - potentiometru de pozitie; hydraulic drive - motor hidraulic; manual drive - actionare manuala; Ferguson cone drive set – reductor; magazine housing - corp magazie

The F/M Separators assembly are mounted on the Magazine assembly end cover at 67.50 ° from the F/M vertical axis. These mechanisms detect RAM B position, the separation between two fuel bundles, between one fuel bundle and RAM Adapter, but also between one fuel bundle and the Shield Plug.

Additionally, the F/M Separators prevent an unwanted axially travelling of the fuel bundles column due to the cooling water hydraulic force in the channel.

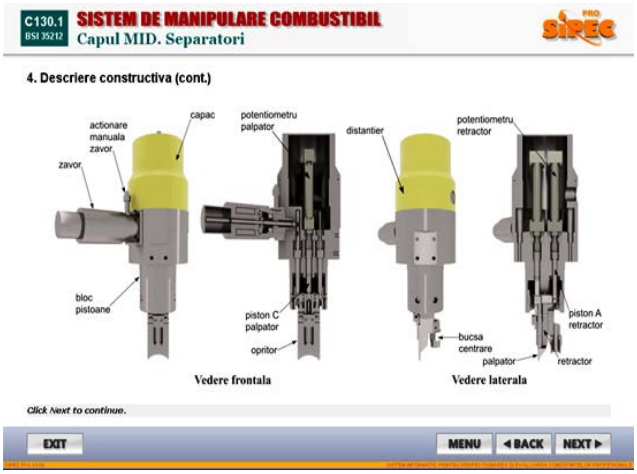


Fig. 4. F/M Separators assembly

separator safety lock assembly - zavor; override manual assembly - actionare manuala zavor; cover - capac; block cylinders - bloc pistoane; sensor linear potentiometer - potentiometru palpator; C piston - piston C palpator; stop side - opritor; spacer separator assembly - distantier; bushing - bucsa centrare; pusher linear potentiometer - potentiometru retractor; sensor - palpator; pusher - retractor; A piston - piston A retractor

The RAM assembly, also called RAM pushers, have six concentric sleeves fitted in an exterior housing attached to the F/M Magazine with a Grayloc clamp and seal ring [4]. The RAM assembly performs different tasks like: transfer and mount the Channel Closure Plug or Shield Plug in F/M Magazine or end-fitting, but also operating the Guide Sleeve Insertion Tool to take-over, carry and lock the Guide Sleeve in the Snout Assembly. Other purposes for the RAM assembly are to push the fuel bundles inside reactor channel and to hold the fuel bundles column against the cooling water hydraulic force inside the channel.

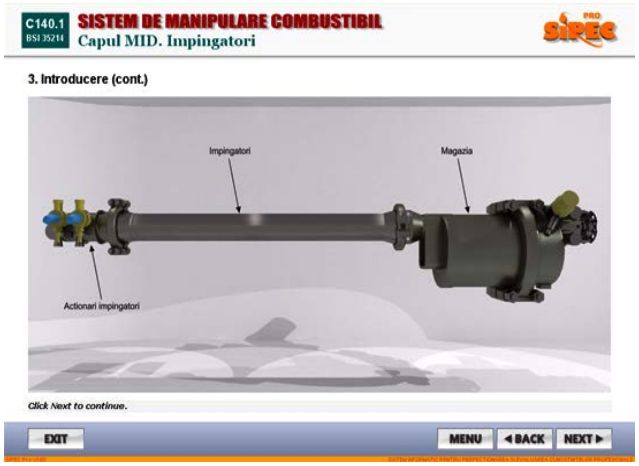


Fig. 5. F/M RAM assembly

RAM assembly drive - actionari impingatori; RAM assembly - impingatori; F/M magazine assembly - magazie

In addition to the above four main mechanisms, to perform normal fuel channel charging/discharging operations, inside the F/M Head Magazine are kept and transported the auxiliary tools and devices: FARE tool, Snout Plug, Shield Plug, Channel Closure Plug, RAM Adapter, Guide Sleeve and its Insertion Tool.



Fig. 6. F/M Auxiliary tools and devices

FARE Tool - scula FARE; RAM adapter - adaptor RAM; Guide Sleeve - manson de ghidare; insertion tool - scula de montaj; channel closure - inchidere canal; Shield Plug - dop protectie biologica

SIPEC Pro

The need for newly-hired personnel training in order to perform specific workplace activities, adding the desire to refresh the knowledge acquired by the older employees of the Institute for Nuclear Research Pitesti led to the developing of Training, Examination and Knowledge evaluation SIPEC Pro e-learning Informatics System, its courses being fully elaborated in the Out of Pile Testing Department.

Some of the main objectives of RATEN ICN are the personnel continuously training, maintaining existing installation and testing rigs commissioning and operating capability. Applied for the Out of Pile Testing Department, these objectives mean training and perfecting the personnel involved in CANDU Fuel Handling System research activities.

So far, the already developed SIPEC Pro courses fully treat subjects related to the Fuel Handling System equipment construction and functioning, presenting additional information about adjustments, calibration methods and maintenance operations.

Each course is composed of an introduction in subject of matter along with general concepts about CANDU Nuclear Reactors, followed by the main information of the course, presented textual or graphic as images and videos (where it is necessary), one chapter for synthesis, conclusions and references. After finishing the course, the trainee can evaluate the acquired knowledge by solving an interactive test.

For a better understanding of the finished course, the questions from the interactive test were structured with four answer choices, every question having a minimum of one correct answer. Also, the test can have questions with four correct answers. Highest mark for every question is achieved only when all possible answers are selected. This type of questionnaire is useful for the trainee, encouraging logic thinking and boosting his memory by eliminating the possibility of random choosing an answer.

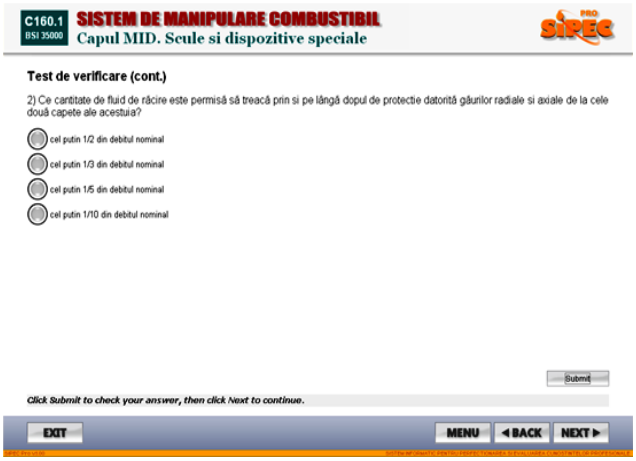


Fig. 7. Example of a SIPEC Pro questionnaire Verification test

How much fluid is allowed to pass through and past the Shield Plug due to radial and axial holes at its two ends?

- at least 1/2 of the nominal flow; - at least 1/3 of the nominal flow; - at least 1/5 of the nominal flow; - at least 1/10 of the nominal flow

Such a course can be developed only after undertaking a thorough research about the subject that will be presented and explained. Mainly, the foundation for these courses was the Institute for Nuclear Research technical documentation.

First step that was made in order to create SIPEC Pro system was gathering, sorting information regarding the CANDU Fuel Handling System and assembling a textual database. These actions took place between 2009 and 2016. The actual developing of the interactive courses with Toolbook Instructor 9.5 software was done between 2012 and 2020.

For a better understanding of the Fuel Handling System equipment and machines, several images were drawn in Autodesk Inventor and Sketch-Up 3D graphic processing software. These images were special edited to show and specify all sub-assemblies, components and the most important parts of the equipment that was treated in the course. Furthermore, for understanding F/M Head components behaviour and interaction with the auxiliary devices there were developed in the same graphic processing software videos which specify all of the steps undertaken by the RAM pushers in order to complete the job for every situation. Prior to the developing stage of this videos there was studied the technical documentation regarding sequences and jobs carried out by the F/M Head for a normal fuel charging/discharging cycle.

Results

Starting from 2012, the new employees in Out of Pile Testing Department attended all developed SIPEC Pro courses to specialize in their field of work. Also, previously employed personnel attended these courses as an opportunity to refresh or correct the knowledge acquired in this period working in nuclear research field.

The entire e-learning programme was a success and promising results were noticed. The involved personnel was able to get appropriate CANDU Fuel Handling information and F/M Head Test rig operating required knowledge.

So far, SIPEC Pro e-learning Informatics System consist of the following interactive courses: ″Auxiliary devices – Snout Plug″, ″F/M Snout assembly″, ″F/M Magazine″, ″F/M Separators″, ″F/M RAM assembly″, ″Fuel Handling System – Fuel transfer equipment″, ″F/M Head – Specialized tools and devices″.

Conclusions

Having in mind the positive feed-back from applying this e-learning method with SIPEC Pro system for the Out of Pile Testing Department personnel, it is recommended to continue this method in order to train the newly-hired employees and to refresh the already acquired knowledge of the previous employed and more experienced personnel.

Collaborations with other INR departments should be envisaged, in order to develop courses which treat different subjects of interest in the field of nuclear research.

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