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Methods for using computer training facilities in studies of special disciplines

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Abstract

The paper considers the practical use of computer training facilities in training of personnel for nuclear power industry and their role in forming professional and special professional competences of graduating students.

The Ural Federal University's Department of Nuclear Power Plants and Renewable Energy Sources possesses special training facilities for training of personnel for nuclear power plants with fast neutron reactors. Software tools and simulators, such as GEFEST, Joker and Syntes codes, a BN-800 analytical simulator and others, are heavily involved in the training process. A variety of computer-aided simulation systems is used by students for research projects.

The paper considers the structure and the components of the BN-800 training system used for training in control of the power unit's reactor and turbine department processes. It also describes process control techniques and the reactor and NPP process control and visualization tools. Mathematical models are described, which are used for real-time modeling and simulation of the power unit's neutronic, thermal–physical and thermal–hydraulic processes.

The use of the analytical simulator is illustrated by a laboratory research project entitled "BN-800 Reactor Power Maneuvering", which investigates the reactor facility power control modes in a power range of 100–80–100% of the rated power.

Keywords: Nuclear power industry; Nuclear power system; Fast neutron reactor; Personnel training; Analytical simulator.

Introduction

Large-scale nuclear power of the future is required to feature guaranteed safety, economic sustainability and competitiveness, no limits on raw material supplies for a long period of time, and environmental stability (low waste technologies). Nuclear power systems with liquid metal cooled fast neutron breeder reactors are one of the potential choices for meeting these requirements [1].

Russia has a long-term experience in construction and operation of sodium cooled fast neutron reactors the evolution basis for which is Beloyarsk NPP. The BN-600 reactor has been successfully operated for over 36 years, and a power unit with the BN-1200 reactor is in the process of reaching its rated power. Currently under development is a BN-1200 reactor design that can be used in nuclear power systems of generation IV with a closed nuclear fuel cycle [2].

One of the major conditions for the successful advance in this innovative avenue of nuclear power evolution is training of highly skilled personnel for the operation and maintenance of systems and components in nuclear power units with fast neutron reactors [3]. Software simulator systems are heavily involved in the educational process, contributing so to high quality of personnel training.

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Methods and techniques

The Department of Nuclear Plants and Renewable Energy Sources (NP&RES) was established in 1961 at the Ural Polytechnic Institute (currently, the Ural Federal University) in connection with the construction of Beloyarsk NPP. The construction of unit 3 with the BN-600 reactor actualized the need for giving the department's graduates specialized training in operation of fast neutron reactors. The unique fast neutron technologies called for a specific approach to personnel training and for a dedicated infrastructure that was developed with a great deal of support from the management of Beloyarsk NPP and Rosenergoatom Concern [4,5].

A long-term experience in training of personnel for nuclear power industry dictated the need for having software simulator systems heavily involved in training. A package of unique software simulator systems has been introduced at the UFU's NP&RES Department, including the following

- TOMAS-1 and TOMAS-2 analytical simulators allowing simulations of normal; transient and emergency states of respectively VVER-1000 and RBMK-1000 units [6];
- Korsar, a code intended for design analyses of transients in VVER NPP circuits in steady-state, transient and emergency conditions;
- GEFEST, a software package for neutronic analysis of BN-type reactors in a multigroup diffusive approximation in a 3D hexagonal geometry;
- Joker, a software package for computational justification of the safe BN-600 NPP operation;
- Syntes, a software package for neutronic and thermal–hydraulic analyses of fast neutron reactors;
- a BN-800 analytical simulator.

In addition, high quality of personnel training is effectively achieved through the approach "Education through Science" that addresses real problems of nuclear power for a streamlined educational process.

A variety of standard computer-aided simulation systems is used by the NP&RES Department's students for their research and graduation projects [7,8]. High-precision Monte Carlo codes are a part of analytical and experimental studies undertaken, beginning in 2011 jointly with the Institute for Reactor Materials, to optimize the composition of homogeneous radiation protective materials [9,10]. Experts and computer facilities of the Institute for Mechanics and Mathematics, the Ural Branch of the Russian Academy of Sciences, are involved in complex mathematical problems (e.g. use of a dynamic programing method for the work optimization routing in nonstationary radiation fields [11]) [12].

Laying emphasis on the simulator training of personnel in achieving the safety of NPP operation, a BN-800 analytical simulator developed by Simulation Systems Ltd. in Obninsk, was purchased by the department in 2008 for simulation of different power unit operational states, including transients and emergencies (Fig. 1).

Fig. 1. BN-800 analytical simulator training.

The simulator has had a special role in the proactive training of field staff for a power unit under construction with the required number of personnel trained by the unit startup time. The simulator will be further used for routine training, retraining and refresher training of the BN-800 personnel [13].

The simulator system comprises five workstations, two (host and standby) servers, a printer and a network switch. All of the simulator components are locally networked. Each workstation includes two graphic monitors, a keypad and a mouse pointing device.

One of the stations is the instructor workstation and the others are operator workstations. Unlike the other workstations, the instructor workstation uses a dedicated instructor format and a dedicated simulator control panel. It also starts up the model and controls all simulator processes, including statement of failures and "remote" control (in-situ) impacts.

The operator station simulates the unit operator workstation. Each of the operator stations may serve as the reactor, steam generator or turbine plant operator workstation.

All relevant data on the status of the unit components is displayed in the operator station monitor screens. The mouse pointing device is used to control equipment and the process. All mechanisms (pumps, regulators, valves and others) are controlled with the use of the icons and buttons in popup control windows.

Relevant information (process parameter values in a digital form and the status of pumps, regulators, valves and so on) is delivered to the operator in graphic formats displayed through the navigation system. The operator uses these formats to control the unit components. Diagrams are used to trace and survey the evolution of typical processes (Fig. 2).

There is a navigation bar with the navigation system buttons, alarm buttons and transition buttons in the lower part of the screen. The upper bar includes sensors for the critical unit process parameters and two reactor control and protection system (CPS) format display buttons. The operator format display options include a generalized format, an emergency, safety and process alarm format, the preceding format and other formats displayed in any simulator monitor.