IGORR7 meeting

Current Status of the PIK Reactor

K.A. Konoplev

Petersburg Nuclear Physics Institute
Russian Academy of Science

Gatchina, Leningrad district, 188350,
Tel:(812)7146735. Fax:(81271)31282.
E-mail: kir@hep486.pnpi.spb.ru

Abstracts

At the end of 1998 the heads of the Russian Academy of Science, the Ministry of Science and Technology and the Ministry of Atomic Energy (the bodies involved in the research work with neutrons) declared the PIK-project as one of the objects of the first priority. They set a task to put it into operation in the next 3-4 years and to organize on its base an international center of neutron research. Realization of this task will depend on the real financing. In the last months there was a remarkable impulse in the construction work.

In the frame of ISTC Project 321-96 Petersburg Nuclear Physics Institute and Research Institute of Technology developed functional training simulator (FTSC) for Reactor PIK. The utilization of FTSC for reactor PIK design examination began.

I

Reactor PIK construction in 1999

At the end of 1998 the heads of the Russian Academy of Science, the Ministry of Science and Technology and the Ministry of Atomic Energy (the bodies involved in the research work with neutrons) declared the PIK-project as one of the objects of the first priority. They set a task to put it into operation in the next 3-4 years and to organize on its base an international center of neutron research. Realization of this task will depend on the real financing. In the last months there was a remarkable impulse in the construction work.

The financing is started. If it will be continued on the same level reactor will be critical in the beginning 2002.

This year the assembling of reactor vault is in progress. Heavy water tank, some ducts for the experimental channels and reactor vessel are installed. Primary cooling system with pipes, pumps and valves are assembling.

Cranes and partly lifts in the building are in adjusting. Installation and adjusting of ventilation and heating systems for the winter season are in progress. Electrical system permits now to refuse of temporary lighting. Physical protection system is also build up as important part for permission on bringing fuel in the reactor site.

II

Reactor PIK simulator

Yu. Bakulin*, K. Konoplev**, D. Ljaljujev*, Yu. Semenov**, S. Shefter*, V. Vasilenko*, V. Zimakov*.

*A. P. Alexandrov Research Ibstitute of Technology (NITI)
188 537, Sosnovy Bor, *Leningrad district,*
Tel:(812-69) 62667 Fax:(812-69) 63672.
E-mail: postmaster@niti.spb.su
*** Petersburg Nuclear Physics Institute Russian Academy of Science (PNPI)*
Gatchina, Leningrad district, 188350,
Tel:(812)7146735. Fax:(81271)31282.
E-mail: kir@hep486.pnpi.spb.ru

This work is done in the frame of Project Activity Report of ISTC 321 —96
“Functional Training Simulating Complex (FTSC) of research reactor PIK”

Reactor PIK simulator (FTSC) is created in Petersburg Nuclear Physics Institute on which physical processes and the operation of reactor PIK equipment are simulated on central computer by Mathematical Model and facility control and information representation are based on display boards.

Requirements for Mathematical Model on simulating processes and reactor equipment are adjusted to full scale training simulator. FTSC has an instructor position and operator position for the operator staff training. The improvement of operating staff training should be regard as serious reserve of the improving of the reactor safety [1]. Quantitatively it's difficulty defined. However, it should be take into account that from 30 to 50 % of incidents at nuclear facilities carried out by the personnel errors.

FTSC has some additional, as compared with full-scale simulator, functional possibilities. For example, the changing of Mathematical Model integration step, acceleration in calculations of dynamic processes, possibilities of the scanning of the information which circulated in Mathematical Model etc. All this stipulates its value as analyzer or as a research-simulating complex.

FTSC PIK is created before the reactor is turning into the operation. The Mathematical Model will be used, for the beginning, for the examination project technical solutions, algorithms of automatic and control in all operation regimes and for the working off technological procedures, that in turn, lead the improvement safety.

Reactor PIK parameters

- thermal power - 100 MW
- thermal neutron flux

  in the reflector - $1.2x10^{15}$n/cm^2s

  in the central vertical beam tube - 5.10^{15}n/cm^2s.
- number of horizontal beam tubes -10
- Diameter of beam tubes entrance flange - 25 cm.
- number of inclined beam tubes - 6
- number of vertical tubes for irradiation of samples - 6

The reactor will be equipped with sources of hot, cold, and ultracold neutrons to obtain beams in different parts of energy spectrum.

The low temperature circuit will make it possible to irradiate samples at helium temperatures.

The branched system of neutron guides (4 for cold neutrons and 4 - for thermal neutrons) of total length ~ 300m allows to transport beams into pure conditions of neutron guide room adjacent with the reactor building. The total number of positions on beams for arrangement of experimental installations - 50

The reactor has three series cooling circuits. Emergency core cooling systems in the event of damage of any circuit are duplicated and in case of loss of electric power supply they are triplicate [2].

Reactor plant consists of linked systems. For example, main cooling system, physical-monitoring system, ventilation et cetera.

Systems are divided on three groups in accordance with the degree of the modeling:

- – **completely simulating system** simulated all equipment and functions which are implemented by this system in normal and in emergency regimes. All alarm and emergency signals are simulated. In total there were distinguished 17 such systems;
- **partly simulating system**– the simulating of the part of system are carried out as in completely simulating system but the rest part of the same system is simulated by logical dependencies as boundary conditions. This boundary conditions might change in the dependence of operation regime or by instructor request. In total there were distinguished 3 such systems;

- **simplify simulating system**– the system the operation of which has not essential influence on control of technological process. System operation is simulated by logical dependencies as boundary conditions, which change in the dependence on system operation regime or on instructor introductions. There were distinguished 17 such systems.

Full number of simulating systems is 37.

List of the simulating systems:

- Reactor
- Control and monitoring
- Primary cooling circuit
- Central experimental channel cooling circuit
- Reactor vessel cooling circuit
- Reflector heavy water cooling
- Cooling pond
- Reactor vault water cooling
- Main intermediate cooling circuit
- Separate intermediate cooling circuit for heavy water
- Emergency intermediate cooling
- Makeup primary cooling water
- Makeup central experimental channel cooling water
- Shutdown heat removal
- Reactor emergency cooling
- Central experimental channel emergency cooling
- Data acquisition and advises (RAKURS)
- Fuel failure monitoring
- Control rods driving gear cleaning
- Leakage collection
- Hydrogen burning in heavy water circuit
- Hydrogen burning in reactor vessel cooling circuit
- Reactor refueling
- Beam gates control
- Radiation monitoring
- Water purification for reactor vessel cooling circuit

- Special sewerage
- Oxygen supply
- Water purification for heavy water
- Ventilation
- Experimental channels sealing control
- Supply for the cold and hot neutrons sources
- CO_2 Supply for the experimental channels
- Cooling tower circuit
- Electrical power
- Diesel-generators
- Nitrogen supply

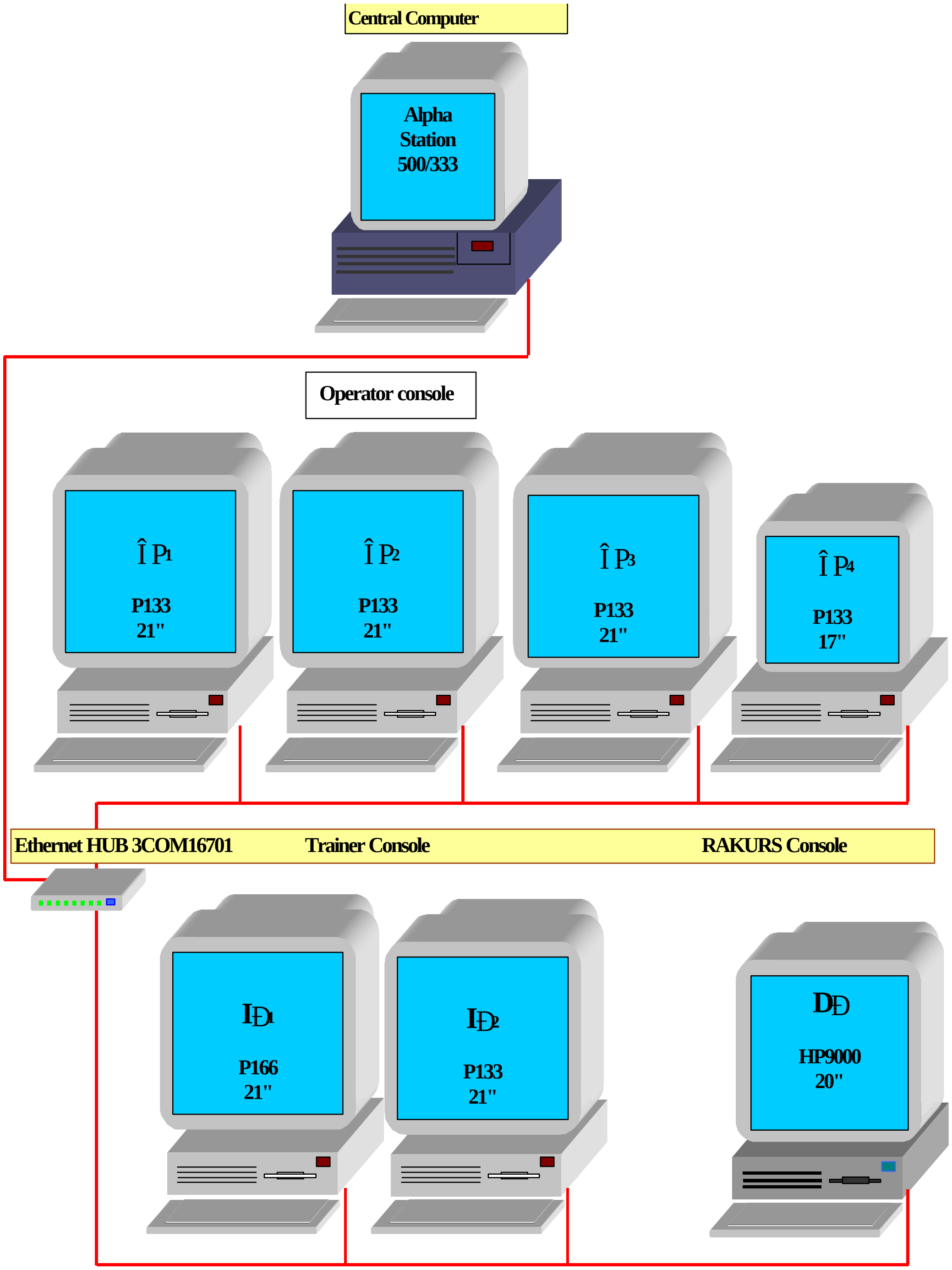
Systems division on three levels is done on the basis of accuracy and limits for simulation. The accuracy of the simulating will be provided the sequence of the operation, blocking and automatics in accordance with analogous processes on real reactors system.

Mathematical Model will be simulated reactor operation in normal and alarm regimes of the operation in real time.

The volume of the simulating equipment may be illustrated by following figures:

- about 1000 units of pipe-line valves
- more then 80 circulating pumps
- 45 vessels
- 40 heat exchangers
- more then 300 electrical devices and 200 drivers
- more then 800 measuring channels
- more then 10000 discrete and 3000 analogous signals.

FTSC consists of central computer, operator position, instructor position, and data acquisition and advises (RAKURS) position.



Structured scheme of FTSC technical means

The striking FTSC part is functional software.

On functional software development it's necessary to take into the consideration the following circumstances:

- the facility consists of great number of technological systems which influence in different extent on facility operation and its safety. Not the all of technological systems are included in simulating list now. But in future it doesn't exclude the possibility to extend the list of modeling systems. Therefore the mathematical model of the facility must have the modular structure for increasing the set of modeling technological systems.
- the great part of facility technological systems presents itself branching light and heavy water thermohydraulic circuits with single-phase coolant that worked in about the same temperature conditions;
- thermohydraulic systems are connected very strong between themselves by hydraulics (through common tanks, purification systems) and by the heat flow through heat exchanges;
- there are a great number of the same type equipment: pumps, heat exchanges, valves, pressurazers and so on;
- algorithms of the automatics and of work control of the same type equipment arranged in different systems in most cases have identical structure.

As follows from the above main time-taking work in functional software development is connects with the creation of programs for the calculation of physical processes in thermohydraulic systems and for control imitation of the equipment that coming in these systems.

These tasks are solved by program package of the calculation of the thermohydraulic PRAGIS and program package of logic modeling of control and of checking systems SAMAON-SKU.

Following assumptions are accepted:

- the coolant is incompressible;
- for transient flows calculations there are used experimental data on of the friction coefficients and of local resistance which received for stationary regimes;
- pressure friction losses are proportional to square of flow rate;
- for calculations of pumps static pressure-flow rate characteristics of parabola type are employed.

Program package for the thermohydraulic calculations is based on non-stationary non-linear model and calculates following parameters in dynamics:

- the flow in pipes branches;
- the pressure in internal piping junctions, in tanks and in pressurizers;
- the temperature in internal piping junctions, in tanks and in pressurizers;
- revolutions and pressure of pumps.

Program allow to simulate wide spectrum of operation conditions included the opening and the closing of valves, the start and the stop of pumps, of compressors, of ejectors and of fans

Mathematical model of the electrical supply systems was created by SELEN package for the automation of electric nets operation. The editor package permits to represent at the display scheme of electric net, to insert in interactive regime and necessary initial data.
The list of alarm introductions was developed. Alarm introductions allow to training instructor to manage effectively the educational process.

For checking software some tasks were used for physical processes (neutrons kinetics, thermal-hydraulic), for operational algorithms and so on. The valuation of FTSC can be done only on the experimental data. PIK reactor is under construction, nevertheless FTSC is in operation. Some tasks have a good analytical or digital solution and some were checked on critical facility.

By FTSC aim it was began the investigation of heat transfer process from reactor active core to heat exchangers of primary/intermediate circuits and further across heat exchangers of intermediate/cooling tower circuit and the releasing of the heat into atmosphere. Special interest in this investigations of heat transfer have transient processes connected especially in winter with the probability of considerable temperature oscillations in primary circuit with the reactivity changing which must be compensate by control bodies.

By special investigations on FTSC there were exposed some undesirable effects that occurs on emergency reactor shut down. Changing of algorithms of automatics switching on that remove such violations of technological processes were proposed.

Further there were planned investigations of technological processes connected with:

- emergency protection;
- seal failure of primary circuit with compensated and non-compensated leaks;
- sharp reactivity changing;
- reactor "iodine pit" and technological systems parameters;
- the optimization of hydraulic regimes of technological circuits.

Tasks range that will be investigated of FTSC naturally will be expanded after the receiving of first results of the simulating and the acquisition experience of the operation.

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References

1.Zacepin A. I., Makin R. S., Rizvanov V. K.
Personal traning. Proceeding of the conference " Research Reactors Safety". Dmitrovgrad, 24-28 November 1997. (In Russian).

2. Gostev V.V., Zakharov A.S., Konoplev K.A., Levandovsky N.V., Ploshansky L.M., Smolsky
Two design aspects connected with the safety of the PIK reactor presently under construction. Proceeding of the Third Meeting of the International Group on Research Reactors (IGORR-III, Sept.30-Oct.1, 1993) Japan Atomic Energy Research Institute, 1994