Russian nuclear power development: main achievements and NPP I&C issues

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1. Introduction

The State owned corporation “Rosatom” is the only monopoly in Russia responsible for NPP design, construction and operation.

The simplified structure of State Corporation “Rosatom” is given below:

- The state monopolies
  - Nuclear weapons sector,
  - Science,
  - Nuclear & radiation safety,
  - Nuclear icebreakers fleet

- The competitive sector comprising nuclear power companies (TVEL, TENEX, “Rosenergoatom” Utility, etc., totally about 90 joint stock companies, including SNIIP)
1.1 World geography of Nuclear Power Plants based on VVER

**Czech Rep.:**
- "Dukovany"-1-4
- "Temelin" 1-2

**Germany**
- NPP “Nord”
- NPP “Rainsberg” (all ShutDown)

**Slovakia**
- NPP “Bogunice” 4 VVER-440
- NPP “Mohovce” 2 VVER-440

**Hungary**
- NPP “Paks” 4 VVER-440

**Ukraine**
- Zaporozhskaya 1-6 (VVER 1000)
- Rovenskaya 2(VVER 440) +2(VVER 1000)
- Khmelnitskaya 2 (1000)
- NPP “Yuzhno-Ukrainskaya” 3 VVER-1000

**Armenia**
- “Metsamor”

**Finland**
- NPP “Loviiza” 1-2 (440)

**Russia:**
- Balakovo NPP
  - 4 VVER-1000
- Kalinin NPP
  - 4 VVER-1000
- Novovoronezh NPP
  - 1 VVER-1000
  - 1 VVER-210 (SD)
  - 1 VVER-365 (SD)
  - 2 VVER-440
  - Kola NPP
  - 4 VVER-440
- Rostov NPP
  - 2 VVER-1000

**Russia and Belorussia: Under construction**
- Rostov NPP
  - 2 VVER-1000
- Novovoronezh NPP-2
  - 2 VVER-1200
- Leningrad NPP-2
  - 2 VVER-1200
- Baltic NPP
  - 2 VVER-1200
- Ostrovetskaya NPP
  - 2 VVER-1000
- Floating and small power NPPs
  - 2 KLT-40C (2x38 MW)

**Bulgaria**
- NPP “Kozloduy
  - 4 VVER-440 (SD)
  - 2 VVER-1000
- NPP “Belene” 2 VVER-1000 construction cancelled

**Iran**
- NPP “Bushehr” 1 VVER-1000

**India**
- “Kudankulam” 2 VVER-1000 under commissioning and construction

**Hungary**
- NPP “Paks” 4 VVER-440

**Ukraine**
- Zaporozhskaya 1-6 (VVER 1000)
- Rovenskaya 2(VVER 440) +2(VVER 1000)
- Khmelnitskaya 2 (1000)
- NPP “Yuzhno-Ukrainskaya” 3 VVER-1000

**China**
- “Tianwan” 1-2 VVER-1000
  - 3,4- under constr.
1.2 Trend of electricity production by NPPs in Russia

Electricity produced by NPP, billion KW*h

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<tr>
<th>Years</th>
<th>2009</th>
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Years
2. Russian nuclear power development since May 2011, including I&C issues

- Commissioning of Unit 4 of Kalinin NPP with modernized I&C in the end of 2011;
- Commissioning of RBMK spent fuel dry storage at mining and chemical plant in Zheleznogorsk (Siberia) in 2012;
- Creation of new international company “Rusatom overseas’ oriented at the world market in 2011;
- Beginning of contracting the equipment vendors for SVBR-100 NPP (new fast breeder of small power with led – bismuth coolant) and for floating NPP
- Further development of cooperation with IAEA (IERICS mission to VNIIAES to evaluate VVER I&C design in 2012, OSART missions, Agreement between IAEA and Rosatom on Nuclear Knowledge Management-2012, several valuable conferences and seminars)
2.1 New company “Rusatom Overseas”, the company profile:

Rusatom Overseas, a subsidiary of the State Atomic Energy Corporation ROSATOM, was founded in 2011 with the aim of promoting Russian nuclear technology on the global market.

Rusatom Overseas acts as an integrator of ROSATOM's complex solutions in nuclear energy, manages the promotion of the integrated offer and the development of Russian nuclear business abroad, as well as working to create a worldwide network of ROSATOM marketing offices.

Rusatom Overseas also acts as a developer of ROSATOM's foreign projects, which are implemented with the build-own-operate (BOO) structure.
2.2 Development and implementation of new I&C systems, platforms, HMI and infrastructure

- Radiation Monitoring System (RMS) developed in 2010-2011 was implemented and successfully tested at Kalinin NPP Unit-4 commissioning (new SW with functional and HMI enhancement, modernized detectors and controllers, were provided by SNIIP, VNIIAES)

- The same case with in-core monitoring and diagnostic system – new HW and additional functions, Kurchatov Institute, SNIIP and subcontractors

- TPTS (originally licensed Teleperm-ME, Siemens) after completion of vast modernization was finally implemented at Kalinin NPP Unit 4, by VNIIA named Dukhova
2.2 Development and implementation of new I&C systems, platforms, HMI and infrastructure (continue)

- Polygons for I&C testing – completion of creation and further enhancement, VNIIA, VNIIAES, SNIIP

- New ecological HMI was designed for RBMK drum-steam separator control and successfully tested at full scope simulator at Leningrad NPP (its main designer is prof. A. Anokhin, head of the joint lab of SNIIP and MEPhI Nuclear University)

- Smart-dosimeter was developed. It contains USB port and combines functions of dosimeter and typical flash memory. It gives the computers users via internet possibility to easily create local and global radiation monitoring systems
3. Development of new NPPs of small power for global market, approach for I&C design

3.1 General information

Customer: JSC «AKME-engineering», Russia, Moscow

Project participants: «JSC OKB Hydropress», Russia, Podolsk (reactor main designer), JSC «VNIIPET», Russia, Sankt-Petersburg (the Project main designer), GNC PhEI, Russia, Obninsk (scientific supervisor)

Equipment Vendors: to be selected on the tenders base.

NPP with SVBR–100 is innovative Project of NPP based on available in Russia technology of reactors with liquid metallic coolant.

Its main features:

1. High level of inherent self protection and passive safety and significant simplification of the design of the reactor as well as entire NPP
2. Possibility to operate with different type of fuel in different fuel cycles (period of operation without refuel not less than 7-8 years).
3. Compact design and maximum factory readiness of the reactor.
4. Possibility of creation of module based structured NPP with power multiplying SVBR-100.
3.2 View of the fast reactor of small power with led – bismuth coolant
3.3 Technical characteristics of the fast reactor of small power with led – bismuth coolant

**Design peculiarities:**
1. Reactor integral arrangement in robust vessel, surrounded by safety body.
2. Hydraulic connections of coolant among equipment of primary circuit are formed by reactor vessel and internals elements without pipelines and furniture.

**Main parameters:**
1. Thermal power, MW 280
2. Steam generation rate, t/h 580
3. Steam pressure, MPa 6.7
4. Coolant temperature at inlet, \(^{0}\text{C}\) 345
   and outlet of the core \(^{0}\text{C}\) 495
5. Time period between refueling, year 7 - 8
3.4 Main principles of I&C design

1. Distributed I&C system with several level of hierarchy.
2. Soft control of NPP technological systems.
3. Availability of the large screen and reserve zone at MCR.
4. Principles of diversity, reliability, physical separation and others, providing high level of functional reliability, including protection against common cause failures.
5. Well developed diagnostic functions.
6. Self-diagnostic of I&C programmable devices
3.5 I&C design peculiarities

1. Regulation of coolant flow rate by changing rotation speed of MCP depending on reactor power for maintaining constant coolant heat up.

2. Full scope diagnostic system of NPP.

3. Providing I&C operability during 7-8 years of continuous NPP operation

4. New tasks of neutron flux monitoring while core refueling, reliable reactor control during start up and operation.

5. Load-follow operation in the range 100–50–100 %.
In order to keep required level of water in drum-separator operator has to maintain the balance between inlet and outlet flows. When evaluating the balance operator percepts indication from the scattered displays having different shapes and scales. Then operator performs mental calculations using the gathered data. Such a complicated procedure is prone to human errors especially under transient modes and stress conditions.

4. New achievements in HMI design for Russian NPPs
4.1. The problem: perceptual and cognitive complexity (example with RBMK drum steam separator)
4.2 The solution: ecological interface design

The ecological interface design (K. Vicente and J. Rasmussen) has been implemented. The horizontal bar below the circle summarizes a few portions of water coming from various sources. Inlet and outlet flow bars are connected with line.
4.2 Just superpose two lines (cont.)

The line is inclined when inlet water flow exceed outlet steam flow, or vice versa. In this case operator must adjust water flow rate so that the line turns to the vertical orientation.

Operator can do that ‘like a shot’ skipping perception of displays’ indication and mental calculation.
4.3 The HMI image

- Three-minute history of water level
- Prediction of available time until the level exceeds the setpoint
- Additional feedwater flow rate
- Main feedwater flow rate
- Dynamically calculated setpoint
- Three-minute forecast of water level
The operator spent 38 min to perform the exercise using conventional interface, while the ecological display reduced time to 12 min and damped down fluctuation of the level.
Recommendations for TWG I&C NPP activities in 2013-2016

- Further development of the requirements to safety and safety-related systems design and operation after Fukushima NPP accident (meetings, conference, TECDOC).

- Post-accidents monitoring systems (meetings on the philosophy, principles, requirements, good practices, TECDOC, Coordinated Research Program).

- I&C design for NPP of small power, including I&C for floating NPP, taking into account their peculiarities (meetings, TECDOCs)

- Development of HMI to support the cognitive activity of NPP operators and enhance NPP operational performance (meetings, TECDOCs).
Recommendations for TWG I&C NPP activities in 2013-2016 (cont.)

- Transference of principles of independency and physical separation to APCS upper level (meeting or special topic in other meetings).

- Further development of methods and tools for NPP I&C V&V (meetings, TECDOC on new approaches and good practices).

- Knowledge management in the organizations which are designing and operating NPP I&C, first of all, I&C for reactor control and protection (participation of I&C specialists in KM schools, in Italy, Russia and others, cooperation with IAEA KM section).
Thank you very much!