Evolution of VVER technology towards NPP-2006 project

V. Kosogorov

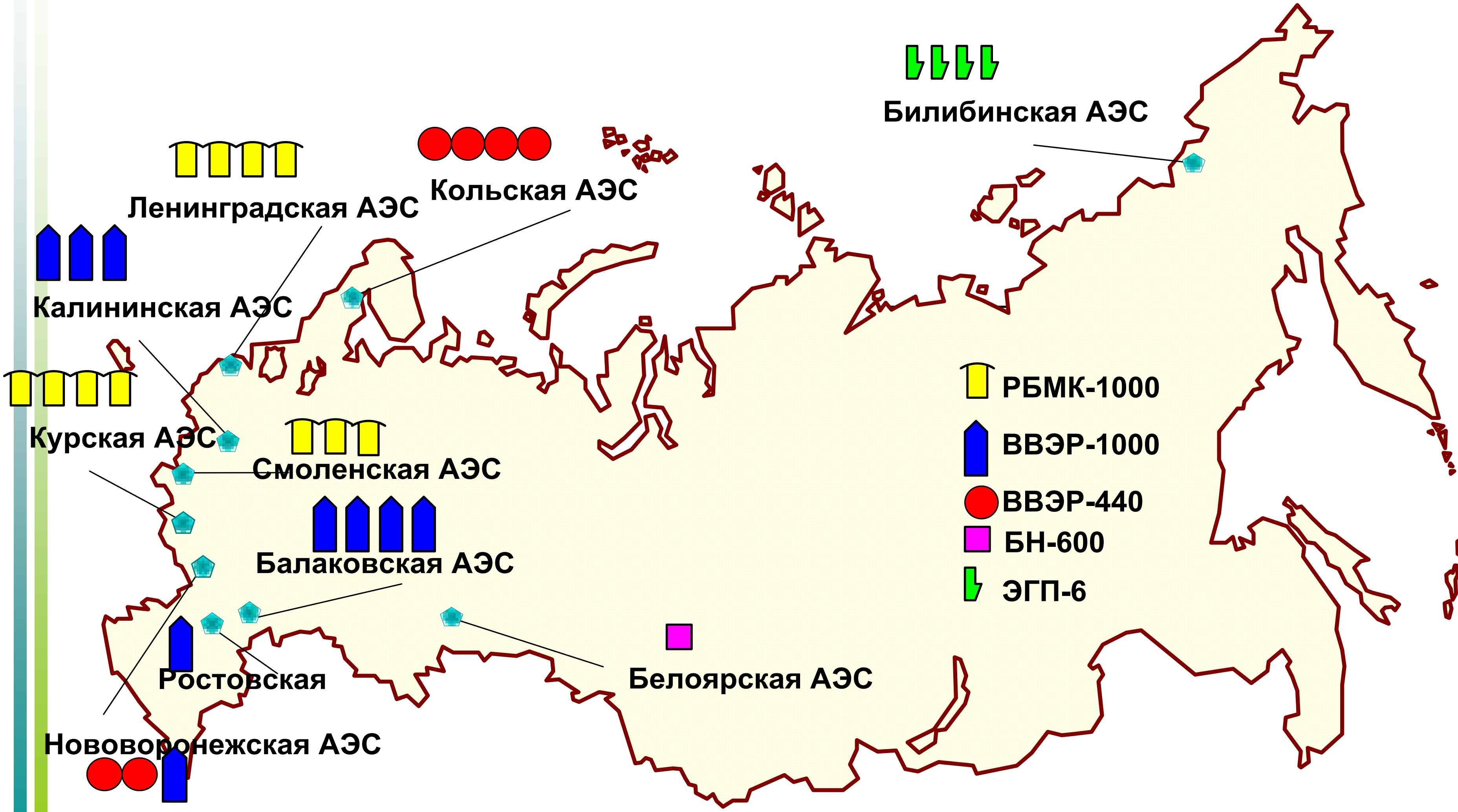
Energoatom Concern OJSC

Moscow, Russian Federation

IAEA 2009.10.28

NPPs of Russia

10 NPPs, 31 units, N_{Σ} =23242 MW



The operating experience of NPPs of Russian design

(as of 01.01.2008)

VVER	–	350 reactor -years
NPPs with RBMK	–	490 reactor - years
NPP with EGP	–	130 reactor - years
NPP with BN	–	60 reactor - years

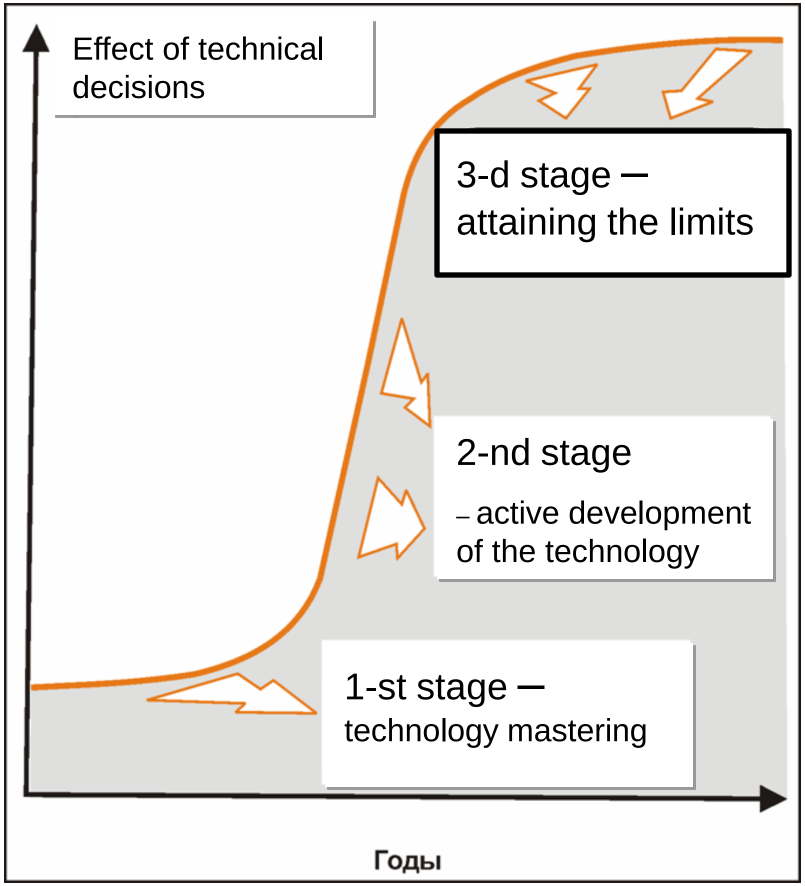
All kinds of NPPs	–	1030 reactor - years

Front units of VVER-type design

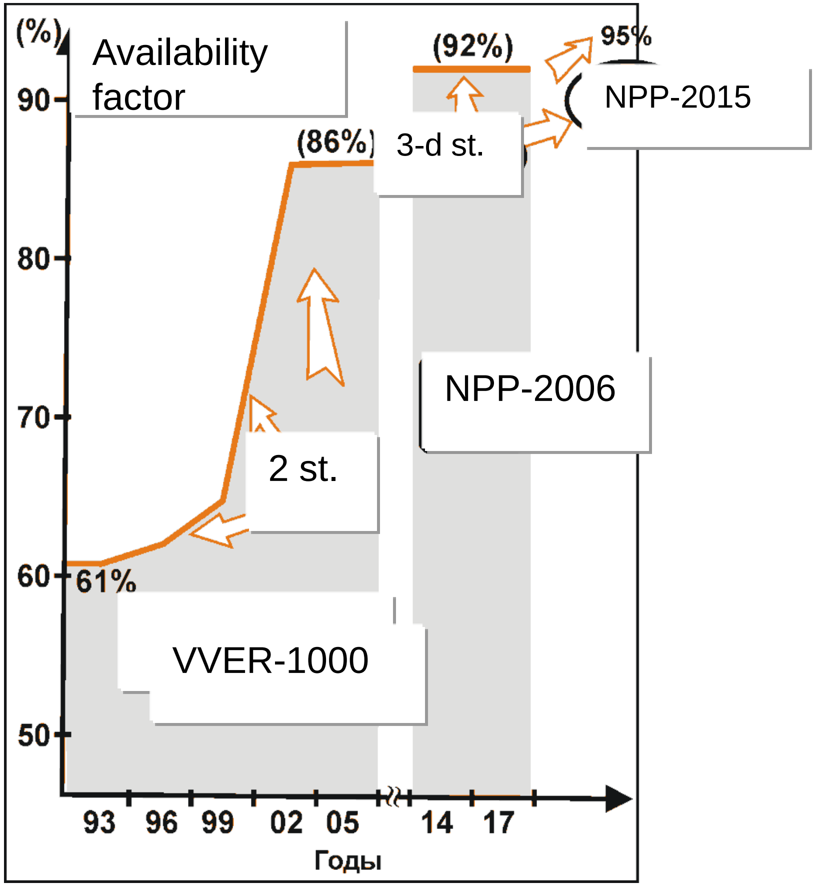
VVER	NPP	Front Unit	Connected to the grid	Total number of units	Note
- 210	Novovoronezh	1	1964	1	
- 70	Reinsberg	1	1966	1	
- 365	Novovoronezh	2	1969	1	
- 440	Novovoronezh	3	1971	16+19=35	
- 1000	Novovoronezh	5	1980	1 + 4 = 5	
- 1000	Zaporogie	1	1984	21	Unified design
- 1000	Tianwan	1	2006	2	Modified design for China
-1000 (1150 MW)_	Novovoronezh -II Lenungrad -II	Under construction Under construction		2 (+2) 4	“NPP-2006” design

Stages of technology development

Theory



Practice



Basic documents governing the development process

№	Documents	Inst. Capacity, GW	Electricity Generation, TW-h	Load Factor, %	NPP Share, %
1	Strategy of nuclear power development in Russia in the first half of XXI century (NS-2000)	52	340	80	25
2	Energetic strategy of Russia for the period up to 2020 (ES-2003)	32/42	230/300	82	20
3	Federal target-oriented program “Development of nuclear power industry complex of Russia in 2007-2010 and outlook up to 2015” (FTP-2006)	41	300	85	20
4	General scheme of power plants placement up to 2020 (Genscheme – 2007)	53/59	372/412	80	23
5	Program of Rosatom State Nuclear Energy Corporation activity for long-term period (2009-2015) (PLA-2008)	33	234.4	82	20

The current targets of development

Characteristics	2006	2010	2015	2020
NPP installed capacity, GW	23.2	24.2	33.0	41.0
Electricity generation, TW-hour/year	154.7	170.3	224.0	300.0
Nuclear share in electricity generation in Russia, %	16.0	16.0	18.6	20-23
Reduction of operating costs (as compared to 2006), %	100	90	80	70
Reduction of operating costs per unit (as compared to 2006), %	100	90	85	70

Priorities of NPPs placement in Russia

European part	**Maximum number of sites**
Siberia	**Isolated facilities**
Far East	**Isolated facilities**

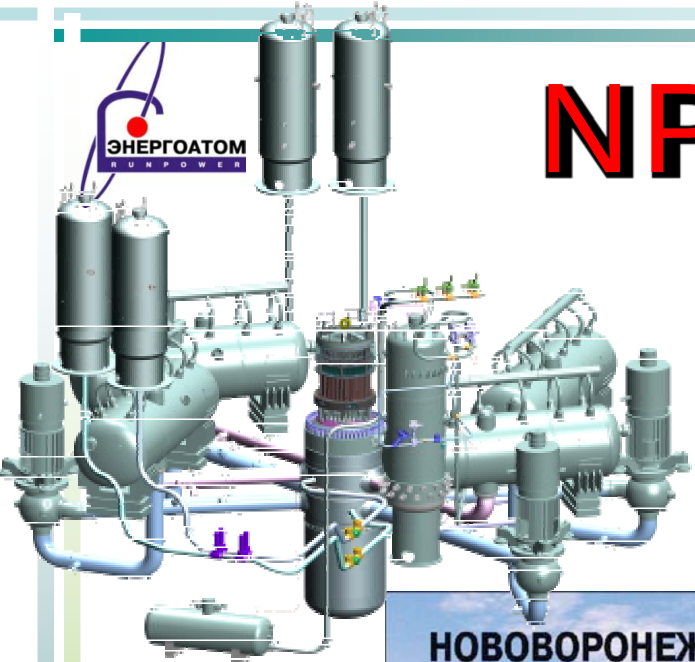
The criteria for choice of alternative construction sites in a region:

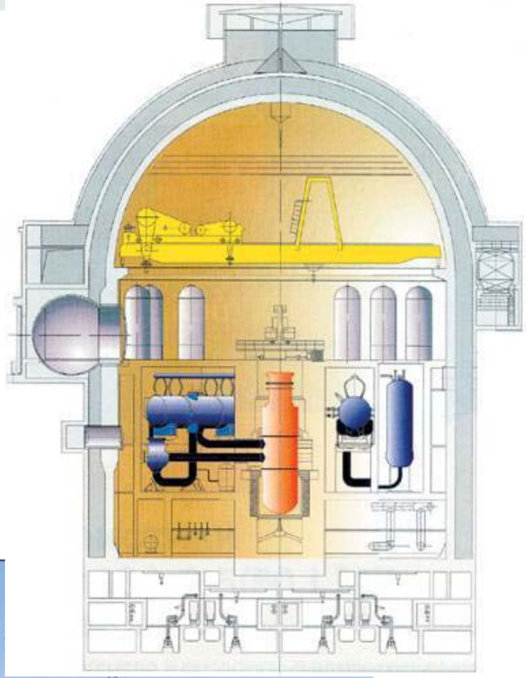
- necessity of power balance improvement;
- minimization of expenses associated with transmission lines construction;
- efficiency of a NPP in comparing with alternative sources;
- minimization of expenses associated with meeting regulatory requirements in various safety areas;
- personel availability for construction und operating stages

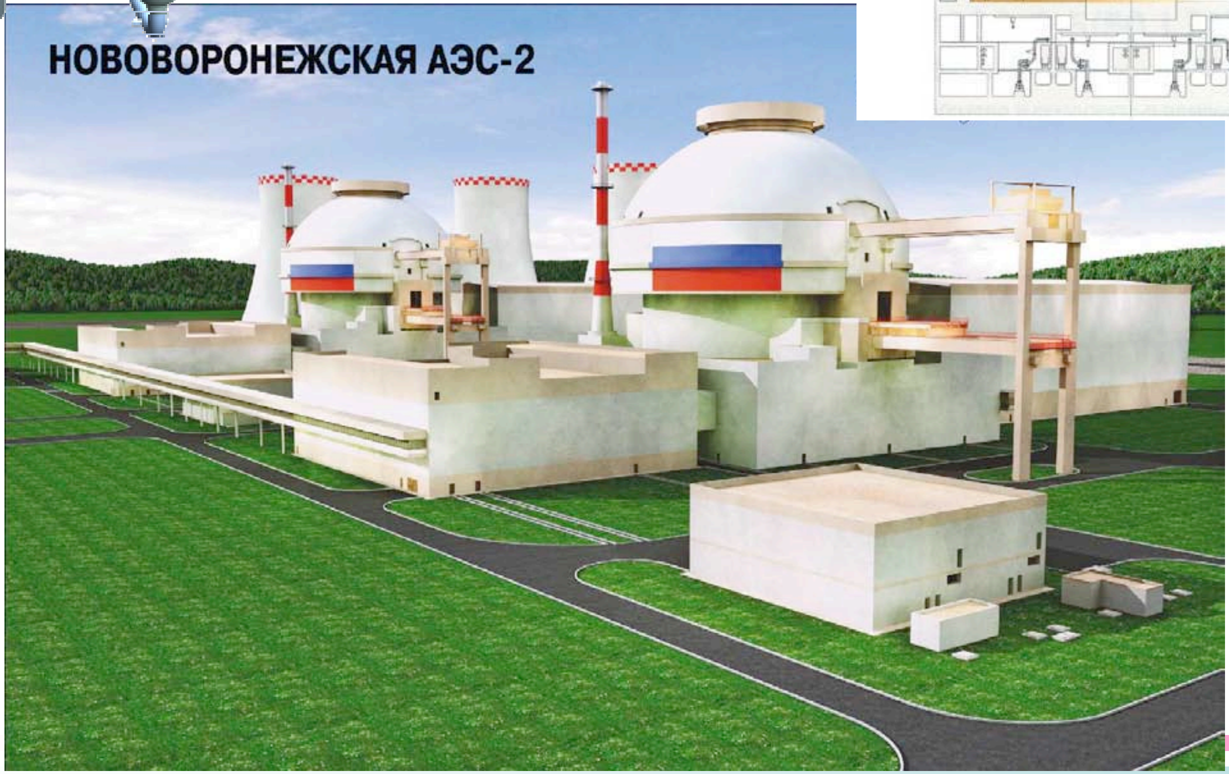
The outcomes from selection of new construction sites for “NPP-2006” implementation

№	Construction site	Number of units	Connection of front unit to the grid	Condition
1	Novovoronezh - II	2 (+2)	2012	under construction
2	Leningrad - II	4	2013	under construction
3	Baltic	2	2016	siting license obtaining
4	Seversk (Tomsk)	2	2015	siting license obtaining
5	Tver (Kalinin – II)	4	2015	siting license obtaining
6	Nizhny Novgorod	3	2016	siting license obtaining
7	South-Ural	2	2016	siting license obtaining
8	Central	2	2017	siting license obtaining

NPP-2006







NPP-2006

- The thermal power was increased up to 3200 MW, and the power unit (gross) efficiency – up to 36.2% due to:
  - elimination of excessive conservatism
  - improvement of the steam turbine thermal circuit
  - improvement of steam pressure parameters at the SG outlet and reduction of pressure losses in steam lines
- Economic efficiency was improved due to:
  - optimization of passive and active safety systems used in NPP-91 and NPP–92 designs
  - unification of the equipment used
  - reduction of material consumption
  - shortening of the construction period duration

The main targets to be achieved with the new reactor designs

- Reactor power rising
- Increasing of main reactor equipment life time
- Load factor increase
- Safety systems improvement as a means to limit occupational exposure and radioactive material release to the environment during normal operation as well as in DBA and BDBA (SA) conditions
- Decrease of radioactive waste volume
- Exclusion of a possibility of sudden large break of primary circuit by means of application of the LBB conception
- Meeting the customer requirements (for example – manoeuvrability, special fuel, seismic conditions and so on) to maximum extent possible

The ways to achieve the above goals are:

- Evolutional method for technical problems solution
- Adapting, to maximum extent possible, all results of previous Scientific and Research Works done for VVER of different modifications
- Account of VVER operation experience
- Meeting the requirements of modern Russian and international standards (IAEA, EUR, INSAG).

Base engineering companies in Russia for NPP project development

R&D institutes “Atomenergoproject”		
Moscow	**Saint-Petersburg**	**Nizhny Novgorod**
Version on the base of “NPP-92”	**Version on the base of “NPP-91”**	**-**

The “NPP-2006” design is developed based on common grounds, in particular:
- Federal law applicable to the peaceful use of nuclear energy
- “Technical assignment for development of the baseline design NPP-2006”, “Technical assignment for Reactor Plant of NPP-2006”
- Applicable norms, rules and standards currently in force in Russia

As a result, for example, the share of unification for the equipment in two versions of “NPP-2006” design was raised from 25% in August 2006 to 47% in August 2007.

The main technical characteristics of the "NPP-2006" design

Parameter	NPP-2006	V-392B	V-320
Thermal power of reactor, MW	3200	3000	3000
Nominal electric power, MW	up to 1200	1000	1000
Steam pressure, MPa	6.8	6.27	6.27
Steam temperature, °C	287.0	278.5	278.5

The main technical characteristics of the "NPP-2006" design

Parameter	NPP-2006	V-392B	V-320
Fuel cycle, year	4 / 5*	3 (max 4)	3
Maximum fuel burn-up, MW-day/kg U	59.7 / up to 70*	55	40.2
Effective hours of nominal power use, h/year	8400	7360	7000
Coolant temperature at reactor outlet, °C	329.7	321	320

* - target

The main technical characteristics of the “NPP-2006” design

<table>
<tr><th>Parameter</th><th>NPP-2006</th><th>V-392B</th><th>V-320</th></tr>
<tr><td>Design NPP lifetime, year</td><td>60</td><td>40</td><td>30</td></tr>
<tr><td>Availability of SA, for reactor-year</td><td>$2.05 \cdot 10^{-7}$</td><td>$4.3 \cdot 10^{-7}$</td><td>$8.3 \cdot 10^{-5}$</td></tr>
<tr><td>Generator -Rotor winding cooling and stator core cooling</td><td>Water</td><td colspan="2" rowspan="2">Gas and water</td></tr>
<tr><td>Generator - Stator winding cooling</td><td>Water</td></tr>
</table>

Alteration of main characteristics

Characteristics	NPPs with VVER-1000	NPP-2006	Alteration %
Rated power, MWe	1000	1150	+ 14.7
Yearly output, bln. kWh	7.5	9.0	+ 20.0
NPP life time (designed), year	30	50	+ 66.7
Average annual duration of scheduled outages	40	25	- 37.5
Availability factor, rel. un.	0.80	0.92	+ 15.0
Constructional volumes per 1 MW, m^3/ MW	620	512	- 17.4
Spent fuel volume (in the form of fuel assemblies), t/bln. kWh	5.5	3.5	- 36.4

Comparison of "Novovoronezh-II" and "Leningrad-II" projects

	NV NPP- II	L NPP - II
Blowdown, make-up system of the primary circuit	Make-up: 3 pumps x 60 t/hour with fulfilling their functions in all regulation range – one in operation, two in reserve	Make-up: 2 pumps x 60 t/hour for "rough" boric regulation and coolant leaks compensation, 3 pumps x 6.3 t/hour for "fine" regulation and leaks compensation
Active part of emergency core cooling system	Two-channel integrated systems of high and low pressure with –ejector-pumps with redundancy of 2x200% and internal redundancy of 2x100%	Separated 4-channel systems of high and low pressure with channel redundancy of 4x100% each
Emergency boric acid injection system	2-channel system with channel redundancy of 2x100% and internal redundancy of 2x50%	4-channel system of high and low pressure with channel redundancy of 4x100% each
Passive core water injection system	**N/A**	4-channel system with channel redundancy of 4x100% with emergency feed-water tanks_
Emergency SG cooling system	Closed-circuit 2-channel system with redundancy of 2x100%	**N/A**
Passive core water injection system	Passive 4-channel system with channel redundancy of 4x33% with 2 tanks in every channel	**N/A**
Passive system of the heat removal	Passive 4-channel system with channel redundancy of 4x33% with 2 air-cooling heat exchangers in every channel	Passive 4-channel system with channel redundancy of 4x33% with 18 water-cooling heat exchangers in every channel

State of “Novovoronezh-II” NPP construction as of September 2009, unit 1

State of “Leningrad-II” NPP construction as of September 2009, unit 1

Thank you

Energoatom Concern OJSC

www/rosenergoatom.ru