Up-to-date issues of VVER Technology Development

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JSC "Concern Rosenergoatom"

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#### Strategic targets of Rosatom

- Increase in nuclear share of power generation in Russia
- Power uprating at NPP Units (capacity factor increase)
- Global nuclear power proliferation

#### **Basis for further development**

✓71 VVER Units constructed
✓8 basic designs elaborated (see slide 3)
✓Need for VVER NPPs (see slide 4)



\* - constructed or under construction



# VVER technology development – priority of Rosatom

#### VVER technolog p Geography of VVER RPs











# CE «GIDROPRESS» COMPANY OF ROSATOR VER technology development – priority of Rosatom

#### VVER-TOI Design. Generation 3+

- power 3300 MW (thermal);
- quantity of RCCAs: 94 pcs.;
- core height: 3730 mm;
- RP equipment service life: 60 years;
- availability of core catcher;
- air PHRS;
- HA-2,3 (self-sufficiency to 72 hours);
- no welds in the area of reactor vessel beltline;
- steam header-free steam generator;
- 2 channels of active safety systems;
- possibility of MOX-fuel application.



#### VVER Unit service life extension

Rostechnadzor licenses obtained :

- Novovoronezh NPP Unit 5 valid till 25.09.2025;
- Kalinin NPP Unit 1 valid till 28.12.2025;
- Balakovo NPP Unit 1 to 18.12.2045

Service life extension activities under way:

Novovoronezh NPP Unit 4 for 15 years (total 30+15+15=60 years);
Kola NPP Units 1, 2 на 15 years (total 30+15+15=60 years);
Armenian NPP Unit 2 на 10 years (total 30+10=40 years)

Basis for service life extension:

- Results of operation;
- Inspection of actual condition;
- Regulatory basis



#### Operation. Current activity trends

#### Unit power uprating

Pilot commercial operation

- Balakovo NPP Unit 3 to 104%;
- Kalinin NPP блоки №1-4 to 104%;
- Rostov NPP Unit 2 to 104%
- Commercial operation
- Balakovo NPP Units 1, 2, 4 to 104%;
- Rostov NPP Unit 1 to 104 %

Uprating activities under way:

- Balakovo NPP Unit 4 to 107%;
- Rostov NPP Unit 3 to 104%

Basis for power uprating

- Operating experience;
- Equipment reserve capacities;
- Lifting up of initial conservatism;
- Improvement of design development (FAs, core);
- Regulatory basis



#### Reduction of power generation cost

Challenges to VVER

- Competition with other technologies (fossil fuel, sun, wind and other technologies);

- Competition with other world nuclear generation companies;
- Movement to closed nuclear fuel cycle (joint operation with fast reactors);
- Decrease in amount of spent fuel.

General requirements for up-to-date NPP designs

- Reduction in specific capital investments;
- Reduction in duration of construction;
- Capacity factor increase;
- Service life extension;
- Decrease in expenditure for fuel



#### Units with two-loop (600 MW-e) and three-loop (900 MW-e) RPs

Creation of a design of power unit with a possibility of choosing a two- or three-loop RP configuration (unified loop) that provides:

- ✓ VVER-highest efficiency factor, capacity factor, availability factor;
- ✓ optimization of fuel consumption, steel intensity, scopes and deadlines of construction and mounting work inside the reactor building, operational expenditure;
- $\checkmark$  usage of spectral control refraining from boron control;
- ✓ safety level not below the requirements for Generation 3+ NPPs;
- ✓ design service life of 60 years;
- ✓ corium retention inside the reactor vessel in the course of a severe beyond design-basis accident;
- ✓ equipment manufacturing to proven technology for AES-2006 and VVER-TOI Project



### Evolutionary design development



Application to the maximum of the equipment out of VVER-1200/ VVER-TOI designs

Industry availability for equipment manufacturing

Corium retention inside reactor vessel in the course of a severe BDBA

Equipment service life – 60 years



Two-loop RP

SafeshutdownearthquaketoMSK-64systemup to magnitude 9;

self-sufficiency - 72 hours

Design optimization



#### Units with two-loop (1200 MW-e) and three-loop (1800 MW-e) RPs

The task is a creation of a unified power unit design with a possibility to choose two-or three-loop configuration, which will allow achieving:

- Competitiveness with the leading foreign companies Areva, Westinghouse (AP-1000, EPR-1600, CAP-1400);
- Reduction of expenses for construction and operation due to:
  - ✓ Actual reduction of construction terms;
  - Saving up of natural uranium in the open fuel cycle (not more than 130 t of natural uranium per 1 GW year of electric power);
  - ✓ RP equipment enlargement ;
  - ✓Modernization of core internals design;
  - Reduction of same-type equipment units of RP and their support systems;
  - ✓Usage of proven solutions for main equipment ;
  - Elaboration a new steam generator using the proven technology of horizontal steam generators;



- R&D focusing on the introduction of new technologies (steel containment, refraining from large-size polar crane, combination of core catcher and reactor vessel etc.);
- Ruling out steam-zirconium reaction due to modernization of alloy XHM;
- Involvement of uranium-238 into the fuel cycle and, thorium, if necessary;
- Application of loadings with different kinds of fuel (UOX from natural and reprocessed uranium, REMIX, MOX and with their combinations) at multiple recycling in the closed fuel cycle;
- Safety and efficiency enhancement due "tolerant" fuel application

A possibility of spectral control is offered to be used as an option as the design development is completed in 2028. The spectral control free design is intended to be developed without 4-5 years



# Evolutionary design development

#### Steam generator PGVV-1200A (alternative)\*

Benefits of primary collector horizontal location

- uniform load on the evaporation mirror;
- better stuffing the steam generator with tubes;
- possibility to arrange economizer section



SG with primary collector horizontal location SG with primary collector vertical location



### VVER-1200A two-loop RP with a new SG

Advantages as compared with 4-loop arrangement:

➢Reduction of the number of SGs;

Reduction of specific metal consumption and construction terms;

Decrease in containment diameter;

Decrease in the time and dose commitments for control, servicing and repair of equipment





# B «GIDROPRESS» Accelopment VVER-1800 THREE-LOOP RP WITH A NEW SG



Design bases

Evolutionary design

Usage of circulation
 loop equipment (SG
 and RCP set) from
 VER-1200A;
 usage of the results
 of design development
 of VVER-1500 reactor
 vessel and internals



#### **Evolutionary-innovative project**

### **Super-VVER**

#### Design development motivation

Relative energy resources of nuclear fuel



- Use in the modern nuclear power of only ~0.4% of natural uranium, mainly uranium -235 isotope, resources of which are limited.

- Huge resources of uranium -238 and thorium -232, energy resources of which are by orders of magnitude higher than of oil and gas.

- Necessity for development of safe, reliable, and stable nuclear power (NP) of Russia on the basis multicomponent NP structure.



### **Super-VVER Design Goals**

- Increase of economic efficiency and competitive ability of the VVER mature technology in different "markets";

- Commitment to industrial (serial) manufacture based on application of global experience and advanced technologies;
- Maximum use of mature technologies based on the lightwater coolant in the closed nuclear fuel cycle (CNFC);
- Decrease of uranium consumption rate to the level of (130 135) t/GWt(el) per year;
- Development of the reactor design, adaptable to requirements of CNFC in the framework of sustainable development concept.



**Evolutionary Super-VVER** 

with Spectral Regulation(VVER-S) – a transitional option

**Expected fuel cycle characteristics :** 

- Breeding factor approximately 0.7 0.8 (0.4 in AES-2006 design);
- Natural uranium consumption approximately 137 t/GWt(el), if the content of uranium-235 in the waste uranium is ~0.1% (197 t/GWt(el) in AES-2006 design, if the content of uranium-235 in the waste uranium is ~0.2%);
- Absence of the liquid and burnable absorbers.



#### **Evolutionary-innovative project**

#### **Evolutionary Super-VVER**



NRC KI

Parameter	VVER-S
Development centers	<u>EDO GP,</u> NRC KI, AEP
Thermal power. /EI, MWt	3500/1300
NPP efficiency, %	33-34
Layout, number of circuits	Loops 2-circuit
Reactor inlet/outlet pressure, MPa	16.2/15.9
Reactor inlet/outlet temperature, °C	287/328,7
Core height/diameter (+screens), m	3,4/4,57
Reactor pressure vessel dimensions height/diameter, m	4. 5/22
RS design development stage	TES
Time necessary to complete R & D and issue of RS engineering design, years *	10
Necessity of a pilot plant construction	_

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### Innovative Super-VVER (SCWR)

Innovative Super-VVER is the water-cooled SCWR (VVER-SCWR). Development of such water-water energy reactors with supercritical steam parameters and regulated neutron spectrum is foreseen by the RF Energy Strategy, which was approved by the Edict of the Government of Russian Federation on November 13 2009. In July 2011 Russia signed Agreement of Generation IV International Forum (GIF) in the line of developing Supercritical Water-cooled Reactors (SCWR).





### OKB «GIDROPRESS»

#### **VVER-I-200** integrated type RP



- Purpose local power generation;
- Conceptual positions:
  - Power range 100-200-300 MW;
  - proven VVER solutions can be used for the core, the drive, structural materials;
  - minimum composition of safety systems.
- Possible parameters of VVER-I-200 N=200 MW.el.;

T<sub>SG outlet</sub> =298 °C;

P=17,64 MPa;

n<sub>FA</sub>=85 pcs.;

h<sub>core</sub>=2500 mm.



#### Improvement motivation

- Competition in the fuel market

- Reduction in specific consumption of uranium

- Providing high capacity factors

- Fuel cycle closing



### Tasks for core and fuel improvement

#### Tasks for evolutionary improvement

- Introduction of mixing and intensifying grids;
- Elaboration of FAs with improved capability for disassembly;
- Increase in uranium content (TVS-4) \*;
- Introduction of Gen II anti-debris filter;
- Justification of fuel application in the maneuvering modes;
- Improvement of core control to reduce the coolant activity if a primary fuel defect is available







\* - Note: Implementation of decisive role of JSC Rosenergoatom Concern in required to obtain the reference 23



#### **Tasks for innovative development**

- Introduction of fuel with initial enrichment > 5% in  $U^{235}$ ;
- Development of the cores with REMIX and MOX fuel;
- Development of tolerant fuel.





OKB «GIDROPRESS»

 VVER technology – reliable basis for successful existence and development of atom for peaceful purpose in the near future and medium-term prospects

 VVER technology possesses a considerable potential of development under the existing requirements for the power generating plants

 Available proven designs allow implementing the evolutionary and innovative trends of nuclear generation development on the basis of VVER technology

 Under the up-to-date conditions successful cooperation with the engineering company – General Designer and the Customer plays the decisive role in the development of VVER technology

# THANK YOU FOR ATTENTION!