Russian practice in the NPP construction optimization and management with the advanced approaches

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## Evolution of the VVER design

<table>
<thead>
<tr>
<th>VVER-1000 V-320</th>
<th>Kudankulam NPP AES-92</th>
<th>VVER-1200 AES-2006</th>
<th>VVER-1200 VVER-TOI</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 channels of active SS</td>
<td>4 channels of active SS</td>
<td>2 channels of active SS with internal redundancy</td>
<td>2 channels of active SS with internal redundancy</td>
</tr>
<tr>
<td>Single containment</td>
<td>Passive SS for all critical safety functions</td>
<td>Passive SS for all critical safety functions</td>
<td>Passive SS for all critical safety functions</td>
</tr>
<tr>
<td>Emergency heat removal through the secondary circuit is limited by a water-supply in the chemically desalinated water tanks</td>
<td>Double containment with a controlled gap</td>
<td>Double containment with a controlled gap</td>
<td>Double containment with a controlled gap</td>
</tr>
<tr>
<td>Core damage in 2-3 hours after SS refusal</td>
<td>Not less than 24 hours protection against fuel melting at full blackout without the operator intervention</td>
<td>Emergency heat removal through the secondary circuit w/out time limitation</td>
<td>Emergency heat removal through the secondary circuit w/out time limitation</td>
</tr>
<tr>
<td>The certificate of conformity to the EUR</td>
<td>Not less than 24 hours protection against fuel melting at full blackout without the operator intervention</td>
<td>Not less than 72 hours protection against fuel melting at full blackout without the operator intervention</td>
<td>Not less than 72 hours protection against fuel melting at full blackout without the operator intervention</td>
</tr>
</tbody>
</table>
Safety level of VVER-TOI power unit

- Hurricanes, tornadoes
  Estimated wind speed is 56 m/s

- Aircraft crash
  Weighing 400 t with the speed of 200 m/s

- Shock wave
  With pressure in the front of 30 KPAS

- Floods
  At the level with provision of >0.01%

- Seismic influences
  MEE 8-point on the MSK-64 scale
# Main technical and economic indicators

<table>
<thead>
<tr>
<th></th>
<th>VVER-1000</th>
<th>AES-2006</th>
<th>VVER TOI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reactor thermal power</strong></td>
<td>3,000 MW</td>
<td>3,200 MW</td>
<td>3,312 MW</td>
</tr>
<tr>
<td><strong>Electric power</strong></td>
<td>1,068 MW</td>
<td>1,198 MW</td>
<td>1,255 MW</td>
</tr>
<tr>
<td><strong>Irrereplaceable equipment</strong></td>
<td>50 years</td>
<td>60 years</td>
<td>60 years</td>
</tr>
<tr>
<td>service life</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gross efficiency factor</strong></td>
<td>35.6%</td>
<td>36.4 %</td>
<td>37.9 %</td>
</tr>
<tr>
<td>of the power unit for average</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>annual conditions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Availability factor</strong></td>
<td>90 %</td>
<td>92 %</td>
<td>93 %</td>
</tr>
<tr>
<td>(at the 18 months fuel cycle)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Quantity of solid radioactive</strong></td>
<td>53,3</td>
<td>57</td>
<td>44,5</td>
</tr>
<tr>
<td>waste, m³/year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Construction time</strong></td>
<td>46</td>
<td>54</td>
<td>48/40</td>
</tr>
<tr>
<td>months</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Time of the plant autonomy</strong></td>
<td>≤24 hours</td>
<td>24 hours</td>
<td>72 hours</td>
</tr>
<tr>
<td>in case of BDBA (LOCA+FBO)</td>
<td></td>
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</tr>
</tbody>
</table>
Passive systems for primary cooling at blackout

Passive heat removal system - PHRS

Hydro Accumulator HA-3

HA-1

HA-2
The industrial site area inside the fence decreased by 23%;

Physical protection perimeter was reduced by 26%;

The sprinkling pools are most approached to a reactor unit that allowed to reduce the length of pipelines of safety important consumers by 40%;

Length of on-site motor roads was reduced by 12 %;

Length of on-site railways was reduced by 33%.
Integrated indicators of the construction duration of AES 2006 and VVER-TOI

**AES 2006**

- Preparatory phase: 24 months
- Construction and installation work: 43 months
- Commissioning: 11 months

**VVER-TOI**

- Preparatory phase: 24 months
- Construction and installation work: 32 months
- Commissioning: 8 months
Optimization of the reactor building layout

Mirror configuration of VVER-TOI provides more space

HA-2 are relocated under the operating deck

AES 2006
Construction process optimization

Main directions:

- Industrialization of construction of **monolithic ferroconcrete structures**
- Introduction of modern **methods of concreting** and effective additives to concrete
- Technology of **reinforcing of the foundation and ceiling slabs**
- Implementation of the Project of the Organization of Construction in the modern **information environment**
- Organization of the **construction mechanization**
- **Automation of welding** of pipelines (especially of a small diameter)
Industrialization of construction of monolithic ferroconcrete structures (1/2)

Production of the reinforcing cages on the batching plant at the NPP construction site.

- Reinforced cages with use of fibrous concrete slabs.
- Vertically connection cages with use of loopback joints put in overlap.
- Horizontally connected cages with use of fittings on screw socket.
1. Containment reinforcing block using steel sheet for retaining mould, weight is up to 190 t

2. Wall reinforcing cage of the surrounding structure using fiber concrete plates with weight up to 20 t; for external shielding wall with weight up to 90 t

3. Large size block of the containment weighting up to 420 t

4. Floor reinforcing cage with fiber concrete slabs for retaining mould with weight up to 20 t

5. Foundation slab made of spatial reinforcing cages with weight up to 40 t
Technology of reinforcing of the base and ceiling slabs

Slab reinforcing technology developed by CNIITMASH (in cooperation with BAMTEC) includes:

- Cross laying of the reinforcing carpets
- Carpet fabrication following the stress distribution
- Use of blockouts

Advantages:

- Fast expanding at limited manpower.
- Industrialization of the reinforcing carpets fabrication.
The concrete of the V60 class is used for reactor building containment:

- Cast concrete (self compacting).
- Curing accelerators.

For introduction of such technologies at a nuclear power plant these researches need to be continued in relation to constructive solutions of the power unit.
Construction Project Organization using 3D modeling
Organization of construction mechanization

- Optimization of locations of the cranes.
- Studies of a gantry crane use.
- Two alternative approaches to introduction of effective technology of equipment installation.
Automation of welding of pipelines

- Large quantity of joints of pipelines.
- Pressure welding method (8 – 76 mm) and a method of magnetically impelled arc butt.
- Correct choose of equipment cuts the labor coefficient of welding of joints of small diameter tubes by half.
- Widespread introduction of the automated welding demands observance at design of certain restrictions on configuration of pipelines.
Main challenges for embarking countries

- People with the experience in NPP construction, operation and maintenance
- Limited knowledge in NPP technology, internal and external hazards and prevention/mitigation experience
- Experienced regulatory body
- Limited technical support to the NPP staff inside the country in case of emergencies
- Timely technical support from abroad in case of emergencies
Ways for overcoming the challenges

Create “greenhouse conditions” for a "first-of-kind" NPP staff

- Selecting the site with minimum effect of extreme external events (3E)
- Choosing NPP design with high ability to withstand 3E
- Ensuring balance of NPP design and the general infrastructure to withstand 3E
- Increasing the staff preparedness to act offline in unforeseen emergencies (increasing the staff engineering knowledge)
- Increasing the staff competence and motivating it to be prepared as a “crew of submarine”
- Minimizing outsourcing of knowledge and maintenance skills
- Strengthening attention to the issues of Safety, Ethic, Knowledge, and Non-blame culture
Conclusions

• Construction optimization and management are directed to the strengthening safety and improving economics of NPPs.

• Fukushima accident revealed several challenges for NPP designs, which were mostly implemented well in advance in the existed VVER design and the rest ones have been already implemented in the new Russian design like AES-2006 and VVER-TOI.

• Further optimization of NPP construction has already been implemented or is consideration for implementation in the new VVER designs.

• For embarking countries:
  • to increase staff preparedness to act in isolation in unforeseen emergency situation,
  • to pay special attention to the readiness of the operational personnel to act with limited external technical support in case of accident,
  • to select site with minimum effect of extreme external event,
  • to minimize outsourcing of knowledge and maintenance skills.
Thank you for your attention