Plant Units Lifetime Extension

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Strategic Task: Keeping Leading Role in Russian Energy Mix

Implementation of LTO program for existing plants

Construction
Plant Life Cycle

- **Design Life Time (30 years)**
- **Additional Operation Period (15-30 years)**

**Targeted upgrading**

**Limitation:** residual lifetime of non-replaceable elements.

Upon receiving new knowledge and experience, there is possibility for justifying longer periods of extended operation.
System and Equipment Upgrading Costs

Mln $

1993-1999: 667
2000-2005: 1549
2006-2010: 4423
2011-2015: 5294

Capacity of units with extended operation lifetime, MW

2001: 417
2002: 834
2003: 2274
2004: 2738
2005: 3780
2006-2008: 4762
2009: 6762
2010: 8362
2011: 9802
2012: 10802
2013: 11802
2014: 13242
2015: 16

3000 MWт
Maintaining Capacities As a Result of LTO

<table>
<thead>
<tr>
<th>1BAL</th>
<th>1BIL</th>
<th>1KLN</th>
<th>1KOL</th>
<th>1KUR</th>
<th>1LEN</th>
<th>1RST</th>
<th>1SMO</th>
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<tbody>
<tr>
<td>2BAL</td>
<td>2BIL</td>
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<td>5NVO</td>
<td></td>
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</tbody>
</table>

- LTO beyond 30 years – done
- LTO beyond 30 years – underway
- new units

As a result of LTO activities, generation volumes in 2015 were 97.5 bln kWh, i.e. ~50% of all plant production in Russia

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Till 2025, the aim of Rosenergoatom is to keep 8 plant units in operation, their installed capacity being above 6 GW

LTO of first-generation units of Russia beyond 45 years

LTO of second-generation units of Russia

4NVO 1,2KOL

3SMO 2KLN 2-4BAL
Main Areas of Operational Efficiency Improvement

1. Reactor power uprate
2. Efficiency output improvement
3. Maintenance and repair technology improvement
Fuel Assembly Upgrading during 107% Uprate

Installing mixing arrays (MA) in TVS-2M assemblies

- **cell type**
- **design features:**
  - no spacing
  - minimum hydraulic resistance

Cell parameters are equalized due to from cell-to cell partial coolant displacement

Turbulent flow as a result of whirling in inter-assembly cell; removal of steam film from fuel assembly surface
SG Upgrading during 107% Power Uprate

Purpose:

- Improve steam output and keep steam humidity characteristics

Steps:

1. Upgrading of steam separation system
2. Installation of SG immersible sheet with variable perforation
3. Installation of additional thermohydraulic measurements system
4. SG separation tests done
Equipment Upgrading to Uprate Power up to 107 Ninst.

**Generator**

Upgrade or replace generator for purpose of 107% power uprate

**Turbine and secondary-circuit components**

Upgrade HP turbine to accommodate greater steam consumption

Upgrading requirements are being developed.
## Upgrading of Mechanical Components in Terms of Power Uprate

<table>
<thead>
<tr>
<th>Reduce process losses:</th>
<th>Improve turbine efficiency – «green» megawatts:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Implement condenser ball-cleaning systems;</td>
<td>• Upgrade turbine flow part;</td>
</tr>
<tr>
<td>• Improve steam reheater separation system;</td>
<td>• Replace pipe systems and improve vacuum;</td>
</tr>
<tr>
<td>• Replace tube condenser materials to reduce number of reloadings for detecting in-leaks</td>
<td>• Implement efficient separation and re-heating systems, and reduce steam humidity upstream steam reheaters, below design value</td>
</tr>
</tbody>
</table>
Steam Reheater

POWERSEP pre-separator

Steam reheaters have been upgraded at 19 units, with power increase of 129.5 MW

POWERVANE separation module
## Replacement of Copper-Containing Components at VVER-1000 during Outage in 2011 - 2019

<table>
<thead>
<tr>
<th>Plant</th>
<th>Unit</th>
<th>Reheater-3000</th>
<th>Reheater-1200</th>
<th>LP Condenser</th>
<th>Other</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LP re heater-4</td>
<td>LP re heater-3</td>
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<tr>
<td></td>
<td></td>
<td>LPR-2_1</td>
<td>LPR-2_2</td>
<td>LPR-2_3</td>
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<tr>
<td></td>
<td></td>
<td>LPR-1_1</td>
<td>LPR-1_2</td>
<td>LPR-1_3</td>
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</tr>
</tbody>
</table>
|                        |      | TA            | Reheater      | Under tendering |}

### Balakovo K-1000-60/1500-2

<table>
<thead>
<tr>
<th>Unit</th>
<th>Year</th>
<th>LP re heater-4</th>
<th>LPR-2_1</th>
<th>LPR-2_2</th>
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<th>TA</th>
<th>Reheater</th>
<th>Other</th>
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</table>

### Rostov K-1000-60/1500-2

<table>
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<tr>
<th>Unit</th>
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<th>TA</th>
<th>Reheater</th>
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</table>

#### Kalinin K-1000-60/1500-1

<table>
<thead>
<tr>
<th>Unit</th>
<th>Year</th>
<th>LP re heater-4</th>
<th>LPR-2_1</th>
<th>LPR-2_2</th>
<th>LPR-2_3</th>
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### Kalinin K-1000-60/3000

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<th>LP re heater-4</th>
<th>LPR-2_1</th>
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<th>LPR-1_3</th>
<th>TA</th>
<th>Reheater</th>
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<tbody>
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<td>1</td>
<td>2016</td>
<td>2016</td>
<td>Austenitic reheaters as per design</td>
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<td></td>
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<td>2016</td>
<td>2014</td>
<td>2016</td>
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<tr>
<td>2</td>
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<td>No copper as per design</td>
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<td></td>
<td></td>
<td></td>
<td>2016</td>
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### Novovoronezh K-500-60/1500

<table>
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<tr>
<th>Unit</th>
<th>Year</th>
<th>LP re heater-4</th>
<th>LPR-2_1</th>
<th>LPR-2_2</th>
<th>LPR-2_3</th>
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<tbody>
<tr>
<td>1</td>
<td>2013</td>
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**Replacement by stainless steel**

**Tendering done; contracts placed**

**Under tendering**
Replacement of Condensers

Exclusion of copper-containing alloys allows implement advanced secondary water chemistry with high pH; and ensure condenser leak-tightness and life cycle.

New pipe systems are from stainless steel or titanium alloys – instead of initial copper-and-nickel alloys.

Advanced design techniques allowed reduce steam resistance of pipe systems, and improve efficiency of non-condensable gas removal, which resulted in increased vacuum with corresponding power uprate by 2.5÷3.0 MW per unit.
Upgrading of Condensers of Turbine K-1000-60/1500-2

Tube bundle before upgrading

Tube bundle after upgrading
Upgrading of RBMK-1000 Turbines

Upgrading of fourth and fifth stages of K-500-65/3000 LP turbines

Power uprate has been achieved due to improved efficiency rate, with no change in reactor thermal power.

• Works done at 21 turbines.
• Exhaust square increased from 6,3 m² to 8,2 m².
• Due to reduced losses relating to exhaust velocity, the turbine unit capacity increased by 16 MW, which resulted in cumulative growth of up to 349 MW in period of low cooling water temperatures.

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Upgrading of K-500-60/1500 Turbines at Novovoronezh-5

For outage-2017 it is planned to upgrade K-500-60/1500 LMP turbine at Novovoronezh-5 due to improved efficiency of the flow part, with planned growth of up to 15 MW. Upgrading includes replacement of LP stages 1÷7 + MP stages 1÷5, with Nτ 100%. Following results of works on TA-13, it is to be decided on significance of the similar works on TA-14.

Growth: Σ ΔN el. = 30 MW
Turbine Equipment Power Uprate, MW

Ball clean.
LPT K-500-65/3000
Reheater

HPT TA K-500-65/3000
HPT TA K-1000/60/1500

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Upgrading is a basis for improving safety, reliability and cost-efficiency, and increasing plant electricity generation.

1 kW of additional capacity is ~10 times cheaper than that from a newly built plant.

during recent 10 years a capacity buildup has been more than 3 GW, which is equivalent to putting 3 new units unto operation.

during recent 20 years a number of equipment failures has increased by ~2.5 times.

safety level has been increased by one order and brought into compliance with up-to-date requirements.
Thank you for your attention!