ALSTOM Atomenergomash LLC developing ARABELLE™ based Turbine Islands for newly constructed and retrofitted nuclear power plants.

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ALSTOM Atomenergomash LLC (AAEM)

- manufacturing of half-speed turbines and generators rated 1000 – 1800 MW for NPP
- integrated turbine hall equipment supply for nuclear applications
- turbine hall equipment retrofit solutions for nuclear industry
- emergency diesel generators packages supply for nuclear applications
- service maintenance of NPP turbine hall

ARABELLE™

2007

49 %
51 %

ATOMEX Europe 2011, p. 2
26 ARABELLE™ are now under construction or operation worldwide.
AAEM LLC
Participation in the new generation NPP projects

Distinctive features of new generation NPPs:

• increased thermal output of the reactor - up 3300 MW
• increased electric output – not less than 1255 MW
• increased efficiency of turbine generator unit – up to 38 %
• application of ARABELLE™ turbine generator unit with 2 LPC with LSB 1730 mm (69”)
• application of HEAS and district heating 500 MW
• 3D model of the turbine hall

Main objectives:

• maximum fleet standardization of equipment
• reduced construction period
• reduced cost of construction and maintenance
The Customer’s extra income in terms of reliability, availability, efficiency and installation and commissioning costs of the ARABELLE™ equipment versus full-speed equipment: from 360 М€ до 430 М€.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Ling Ao 1</th>
<th>Ling Ao 3</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine speed</td>
<td>3000 rpm</td>
<td>1500 rpm</td>
<td>ARABELLE™ is half-speed</td>
</tr>
<tr>
<td>Machine room size</td>
<td>99 x 59 m</td>
<td>99 x 59 m</td>
<td>Same footprint</td>
</tr>
<tr>
<td>Reactor thermal output</td>
<td>2904 MWth</td>
<td>2904 MWth</td>
<td>Same reactor conditions</td>
</tr>
<tr>
<td>Cooling water temperature</td>
<td>23 °C</td>
<td>24 °C</td>
<td>+1°C warmer for unit 3</td>
</tr>
<tr>
<td>Feedwater pumps drive</td>
<td>Turbine</td>
<td>Motor</td>
<td>Motor driven is nowadays standard</td>
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<tr>
<td>Output (net of feed-water pumping power)</td>
<td>Ref.</td>
<td>Ref. + 81 MWe</td>
<td>ARABELLE™ architecture allows to boost the output by more than 8%</td>
</tr>
</tbody>
</table>
AAEM LLC
ARABELLE™ - standardized technical solutions

To Match Any Commercially Available Reactor

EPR

ESBWR/ABWR

VVER 1000

AP 1000
AAEM LLC – integrator of turbine hall

- Maximum unit output:
  - 1550MW in operation
  - 1750MW under construction

- Longest last stage blade:
  - L = 1750mm

- Maximum steam turbine efficiency:
  - Gross efficiency > 37%

- Maximum Steam turbine safety and reliability:
  - Reliability 99.97%

- Low construction costs thanks to compact design

- Low total operation cost

- The largest reference list
AAEM LLC
ARABELLE™ - compact design

- Moisture Separator
- Reheater

68 bar

10.43 bar

3.4 bar

68 bar

10.43 bar

3.4 bar

Length of turbine set – 37,5 m
Weight of turbine set – 1880 t

HIP turbine section

LP with LSB 1730 mm
AAEM LLC
ARABELLE™ - design features

IP Exhaust

The 4-pole generator

Independent LP module

2- stage MSR
AAEM LLC
High reliability indicators

ARABELLE™ - Extensive positive feedback of experience

5-year period 2001-2005
Alstom data derived from external EDF data (290 unit years)
References for benchmark collected from NERC (508 unit years)

Forced Outage Rate

<table>
<thead>
<tr>
<th>Nuclear steam turbines</th>
<th>Alstom fleet</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1,000 MW</td>
<td>0.078%</td>
</tr>
<tr>
<td>&gt; 1,000 MW</td>
<td>0.068%</td>
</tr>
<tr>
<td>&lt; 1,500 MW</td>
<td>0.023%</td>
</tr>
<tr>
<td>&gt; 1,500 MW</td>
<td>0.292%</td>
</tr>
<tr>
<td>US average</td>
<td></td>
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</table>

ATOMEX Europe 2011, p. 10
The main properties:

- MSR installation 2 x 50%, Horizontal
- LP1/2 duplex heaters 2 trains, Horizontal
- LP3/4 heaters 1 train, horizontal.
- HP6/7 heaters 2 trains, horizontal.
- Turbine building footprint: Length = 91.9 m, Width = 57.2 m, Building height ~ 50 m.
- District heating heaters 3, located inside the TH building.
- Main cooling water pumps - 2 x 50%.
- Condensate extraction pumps - 3 x 50%.
- Main FW pumps - 4 x 33%.
- Start-up FW pump - 1 x 5%

Operation and maintenance indicators:

- Availability - 97.5 %
- Reliability indicators - 99.7 %
- Capability - 1256 MW
AAEM LLC
Outsourcing foreign manufacturers of NPP Turbine Hall equipment

AAEM – Plant Integrator
AAEM LLC
Heat sink, district heating and HEAS optimisation

Modular condenser

Main circulating water pump

LP turbine selection

Condensate pump
Cold-End optimising is key for plant economic performance

- Direct impact on Cost of Electricity

![Diagram of nuclear reactor systems](image)

- **Heat sink optimisation**

- **Evaluated MWe**
  - Extra net MW * Evaluation factor

- **Investment Cost**
  - Investment total cost based

- **Owner's Benefit**
  - Net present value
AAEM LLC
ALSTOM’s experience in conventional island equipment retrofit
World leader in component and integrated retrofits

Component retrofits

- Alstom: 42%
- Others: 16%
- 26%

Integrated retrofits

- Alstom: 64%
- Others: 12%
- 9%

Market share analysis represents period FY04-FY08.

Source: Internal

780 cylinders retrofitted (320 retrofits of third party machines)
Leading the concept of integrated retrofits for turbine island
AAEM LLC
Retrofit. Design procedure

Lazer equipment utilization at site

Integrated instruments for design and calculations
Interface analysis for steam turbines of the other manufacturers
Original design

Double flow cylinder - reactive type blading

Single flow cylinder – reactive type blading

Inner casing components optimization

Various retrofit options implemented

Turbine producer not involved

Targeted output achieved and turbine problems cured thanks to the selected technical retrofit options
Generators retrofit
Nuclear Rewind, Upgrade & Retrofit

Capability

Performance (MVA, MVAR, efficiency, reliability …)
Outage time
Extended life time

Replacement Generators

Integrated solutions to fit new generators within existing environment, requalification of auxiliaries, new excitation systems, functional scope

Generator Mid-Sections

“Plug and operate” solutions: stator replacement, rotor replacement or rewind, new excitation systems, requalification of auxiliaries

Generator Rewinds / Upgrades

Stator rewinds, rotor rewinds, new excitation systems, technology changes, additional loops (water)

Maintenance

Parts and Field Services

Solution depending on customer need.
AAEM LLC
Retrofit. Consolidated data for the operated turbine

- K-1000-60/1500-2 - 1500rpm
- 1 x HP double flow module
  - 2 x 7 stages
  - Active type blading
    - Disc-and-diphram design
    - Welded rotor
  - Полный подвод пара
- 3 x LP double flow module
  - 2 x 7 stages
  - Active type blading
    - Disc-and-diphram design
    - Welded rotor

Last stage blade: 1450mm (57”) на φ2700mm – 18,9m²
AAEM LLC
Balakovo NPP Retrofit
HPC and LPC scope options

New HP cylinder

- Active type blading (disc-and-diaphragm design)
  - Finalization of the blading type active versus reactive depends on ratio expenses-profit
- 9 stages per flow
- Preliminary scope of works includes:
  - Bladed rotor
  - Diaphragm
  - Diaphragm sockets for 4-9 stages
    (operated 1-3 stage sockets of diaphragms remain unchanged)
- Welded rotor
- Full arc admission

New LP cylinder

- Reactive blading
- 12 stages per flow
- Preliminary scope of works includes:
  - Rotor
  - Stationary and moving blades
  - New sockets of blades – inner casing shall remain unchanged (subject to additional estimation)
- LSB 57”
- Drum type welded rotor
Conclusion

1. Currently 33 out of 38 nuclear units rated 900 MW and over are equipped with low speed turbines. 26 of them are based on ARABELLE™ technology.

2. Tests of the 1000MW ARABELLE™ Half-Speed Turbine Plant conducted in the 3rd power unit at Ling-Ao NPP (China) in 2010 have shown an electric power increase of above 8% versus full-speed double-flow turbine design given the same conditions on-site.

3. According to Alstom/AAEM research, the Customer’s extra income in terms of reliability, availability, efficiency and installation and commissioning costs of the ARABELLE™ equipment versus full-speed equipment would vary in the following range: € 360 million per unit at the rate of € 25/MWh, or € 430 million per unit at the rate of € 30/MWh.

4. 2011 agreement is reached to involve AAEM with ARABELLE™ technology for the participation in new nuclear units to be constructed in Russia and abroad.

5. Basing on Alstom engineering solutions, AAEM adds value to its competence in retrofitting equipment for nuclear power plants in operation.
Thank you for your attention!