ARABELLE™ STEAM TURBINE
FOR NUCLEAR POWER PLANTS
Performance to boost your nuclear reactor
Today’s power markets have become highly competitive. It is of prime importance that your nuclear power plant operates at maximum performance and availability: the whole power plant, not just nuclear steam supply system, but also the complex equipment that converts the steam into electricity.

Alstom can help you meet this challenge. Alstom designs, manufactures, installs and maintains all the critical power conversion equipment of a nuclear turbine island: steam turbine and turbogenerator, moisture separator-reheaters, condenser and pumps, low and high pressure feedwater heaters, and more.

Alstom’s nuclear power conversion solutions are based on its ARABELLE™ steam turbine technology platform, with its superior performance and exceptional reliability. ARABELLE™ steam turbines can accommodate power outputs ranging from 900 MW to 1,800 MW – the largest turbines in operation worldwide for the past 10 years are ARABELLE™ steam turbines with a 1,550 MW power output provided with extremely high availability. And because Alstom has developed the other key equipment of a nuclear power plant conversion system in co-ordination with the ARABELLE™ family, you, as plant owner, can benefit from an optimal power integrated conversion package.

Alstom has also made your decision-making easier. We can offer you products and systems integrated into operational packages that range from a turbine-generator package to a complete turbine island. As a result, our solutions cover the full power conversion process for any major nuclear steam supply system (NSSS) available on the market.

Alstom is the market leader for nuclear steam turbines and other key nuclear power conversion equipment. Of the 450 nuclear reactors in operation or construction worldwide, three out of 10 use Alstom steam turbines and four out of 10 feature some Alstom equipment. For the past 30 years, Alstom has demonstrated its skills and leadership as a nuclear power plant equipment manufacturer and integrator through an uninterrupted set of projects, both for new and retrofitted nuclear plants.
ARABELLE™ steam turbines: the benefits

More MW: a compact, powerful, efficient and reliable turbine
- 60% of the expansion through highly efficient single flow
- A unique combined HP/IP module
- Standard interface / footprint for 50 Hz & 60 Hz
- Based on mature 1,550 MW unit

Adapted to all reactor types
- Fully adaptable steam path
- From 900 MW to 1,800 MW, 50 or 60 Hz
- For any backpressure and co-generation application

LP size optimised for any site conditions
- Two last-stage blade sizes for each frequency (50 Hz and 60 Hz)
- A blade design that has demonstrated its reliability
- Two or three LP modules for optimum vacuum fit

Welded rotors for reliability and secure delivery
- High resistance to Stress Corrosion Cracking (SCC)
- Excellent reliability, fewer inspections required
- Smaller forgings more available

Designed for ease of maintenance
- Easy access for maintenance
- Easy adjustment of LPs with independent structure
- Compact arrangement with fewer bladed rows
ARABELLE™ is not just a product. It is a family. Alstom’s integration capabilities are built on the solid foundation of a full in-house product range covering the key components of nuclear plant turbine islands. The focus is on the performance improvements that can be obtained from the ARABELLE™ steam turbine through optimal compatibility with the turbogenerator, the moisture separation reheaters and the condenser to get “more than just the sum of the key components” and ultimately optimise the power conversion from the nuclear reactor’s steam.

ARABELLE™ turbine-generator package: get more than just the sum of the key components

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Gigatop 4-pole turbogenerators

With over 30 years’ development and more than 1.5 million hours of operation, Alstom has accumulated vast experience with very high rating 4-pole turbogenerators for nuclear power plants. The Alstom Gigatop 4-pole turbogenerators complement the ARABELLE™ steam turbines with products ranging from 900 to 1,800 MW, enabling high output with almost 99% efficiency. Their design features have been judiciously combined to optimise reliability and facilitate maintenance:

- A modular stator casing with a cylindrical mid-section – easy to transport and maintain
- Stator bars with stainless steel hollow cooling tubes and stainless steel water chambers separated from electrical connections – corrosion resistant, highly reliable independent of water chemistry
- A stator end-winding support structure with two solid glass fibre rings and a mechanical retightening system – minimal vibrations, short maintenance time
- A special compact rotating brushless exciter – reduced maintenance effort (no brushes), short overall shaft line and corresponding turbine hall length
- Triple circuit seal oil system for high hydrogen pressure up to 6 bar – optimised turbogenerator power density, extremely low hydrogen consumption.
Process equipment
Alstom has extensive know-how in heat exchange across all types of power plants, including nuclear applications. Alstom nuclear heat exchangers are adaptable to any reactor output level, delivering maximum performance and reliability and facilitating maintenance.

- 2-pass moisture separation reheaters (MSRs) for efficient moisture separation at high reheat temperatures – increased plant performance
- Complete, integrated condensing systems – the condenser itself, necked low-pressure heaters and desuperheating system, condensate extraction pumps, a vacuum system and an optimised bundle arrangement
- Circulating water pumps
- HP & LP feed water heaters with the smallest temperature differences – maximised performance
- Compact feed water tanks with integrated deaerators.

Plant Integrator™ – creating customer value

Plant Integrator™ is Alstom’s solution methodology designed to create added value for customers. Plant Integrator™’s starting point is the customers’ viewpoint. It then systematically analyses, measures and optimises the specific customer benefits desired, technically, economically and ecologically. As a result, Plant Integrator™ matches customer needs and priorities with products and services, delivering a thoroughly tailored solution and maximising customer value. This then becomes the benchmark for future fine-tuning and upgrades.

The unrivalled Plant Integrator™ offering from Alstom covers the full palette, from single component packages and control systems to turbine islands, operation and maintenance services, as well as retrofit solutions.

Plant Integrator™ benefits to customers:
- Improve cash flow – by achieving lowest costs
- Generate more power
- Increase installation efficiency
- Burn less fuel
- Improve operational flexibility.
What makes ARABELLE™ unique

An innovative architecture
Previous-generation nuclear turbines feature one double-flow high-pressure (HP) cylinder followed by four or six low-pressure (LP) flows (with two or three LPs, respectively) for final expansion to the condenser. The ARABELLE™ turbine offers a new architecture where the steam first expands in a single-flow HP path. After moisture separation and reheat, it then expands in a single-flow intermediate-pressure (IP) section before going through the four or six low-pressure (LP) flows.

This unique ARABELLE™ architecture makes maintenance work much easier.
1. It needs only four steam readmission butterfly valve sets instead of six. This facilitates maintenance. In addition, the butterfly valves are installed at the level of the HP/IP cylinder, accessible from a platform above the MSRs, instead of hanging above the operating floor in front of each LP cylinder.
2. The LP steam admission pipes are entirely below the turbine operating floor. This arrangement helps reduce maintenance duration and cost, because maintenance of the LPs does not require disassembly of the inlet pipes. Large lay-down areas are available alongside the LP cylinders, further facilitating maintenance.
LP-exhaust with independent structure

In previous-generation turbines, the LP inner casing is supported by the LP outer casing, which in turn is supported by the turbine table. Distortions of the outer casing or load variations on the table induced by vacuum or condenser weight variations during operation will affect the relative centring of the rotating and fixed parts. This issue becomes more critical with the very large exhaust structures that characterise modern nuclear plants. The ARABELLE™ LP cylinders are designed with independent structures. The LP inner casing is connected at each end to an end-wall, which integrates the rotor bearing housings. The LP outer casing, which no longer acts as a support, simply becomes an envelope rigidly welded to the condenser, which is supported on the basement floor.

This simple design improvement provides many advantages:
1. The turbine load on the foundation is greatly reduced.
2. The load on the table is not affected by the vacuum variations nor by the forces transmitted by the condenser (through changing water temperatures).
3. This independent structure also makes the relative centring of the moving and stationary parts easier, more precise and more stable. Very reliable vibration behaviour is the result.

Welded rotor technology

Welded rotor technology is a key Alstom steam turbine and gas turbine innovation, which has been continuously improved over the past 80 years to serve larger and larger units.

♦ Compared to a shrink-on disk design, welded rotors encounter reduced stresses and provide better resistance to Stress Corrosion Cracking (SCC).
♦ Compared to monobloc rotors, welded rotors feature smaller forged cylinders (which are welded together), meaning that sourcing and delivery are easier and more secure.
High-efficiency single-flow expansion
The most striking feature of the ARABELLE™ architecture is its single-flow steam expansion featuring blades with higher aspect ratio. This ensures higher efficiency due to the reduction of secondary losses at the root and the tip of the steam path. The result is greater turbine performance, with an overall efficiency gain of around 1%.

To reduce overall turbine length, the HP and IP expansion sections have been grouped into a combined HP/IP cylinder, similar to those used in fossil fired applications. The compact HP/IP module alone, with the same footprint for both 1,500 and 1,800 rpm applications, can produce up to 1,000 MW.
The LSB is optimised through detailed 3D modelling, validated in numerous laboratory tests and manufactured through high-precision forgings. An integral streamlined snubber for blade interconnection and continuous lashing greatly increases stage stability. It helps avoid vibrations, which such long blades with high-aspect ratios could otherwise undergo in service. A curved-entry, fir-tree root fastening provides for excellent transmission of effort to the disk, but also facilitates transportation and inspection.

Efficient, reliable blading
Alstom has leveraged over 35 years of experience in nuclear power plants, and more than 100 years in steam turbine technology, to develop – and continuously improve – its efficient and reliable turbine blade family.

All ARABELLE™ turbine blades feature three-dimensional profiles to optimise their aerodynamic performance.

- Stationary stages feature a welded platform design for high reliability, especially for the HP stages, but that also yields better aerodynamic optimisation of the end-wall conditions, reducing the secondary losses. This robust design is perfectly adapted to the large volume flow found in today’s nuclear power plants.
- All rotating blades, other than the Last Stage Blade (LSB), are designed with integral shrouds to minimise losses. They are manufactured as single pieces, i.e. no loose parts, and assembled through a forked and pinned root fastening design: an extremely robust solution. The sealing ridges are machined after assembly for optimum performance, and a 360° banding ensures consistently good frequency control and reliability.
Large steam turbines in action in nuclear power plants

Alstom supporting the China nuclear program for more than 20 years

Alstom has been at the forefront of designing and installing nuclear turbine islands for the past 30 years, with all kinds of nuclear reactors. Our long-standing expertise is unrivalled. The following projects are just a few examples of our impressive track record.

**Ling Ao Phase I and II**
1,980 MW nuclear turbine island.
Ling Ao was first commissioned in 2003 – several months ahead of schedule – with two 990 MW units. Alstom designed, delivered and supervised the erection of the complete integrated turbine island, including the circulating water pumps. Alstom also delivered the emergency diesel generators and the safety pumps for the nuclear island.
Ling Ao 3+4 Turbogenerators packages for 2160 MW turbine islands were also ordered in 2005. Featuring ARABELLE™ technology, the units will deliver starting in 2010 decisively higher output than previous units. For this project, a significant transfer of technology and manufacturing sharing with our long term partner DECL has been implemented.
Leveraging on this solution, several similar projects are under construction in China, such as Hongyanhe, Ningde, Fangjiashan, etc.

**Daya Bay**
1,968 MW nuclear turbine island.
Daya Bay was the first nuclear power plant in China. It started commercial operation in 1994. Alstom designed, delivered and supervised the erection of the complete integrated turbine island, based on two 984 MW units. Alstom also delivered the emergency diesel generators and the safety pumps for the nuclear island.

Leveraging on this solution, several similar projects are under construction in China, such as Hongyanhe, Ningde, Fangjiashan, etc.
A strong footprint in France, the leading country in nuclear

Alstom has provided turbine-generator sets to all 58 EDF French nuclear power plant.

Civaux
3,100 MW nuclear turbine island.
The Civaux nuclear power plant started commercial operation in 1998. It includes two 1,550 MW ARABELLE™ steam turbines and their corresponding Gigatop 4-pole turbogenerators. Today, this still represents a world output record for an operating turboset. The reactors are of the Areva advanced “N4” type. Under a number of separate component contracts, Alstom designed, delivered and erected the turbine-generators, plus the bulk of the turbine island mechanical and electrical auxiliaries, including condensers, feedwater reheaters, and condensate extraction and circulating water pumps. A power plant extension is now under construction. It will include one ARABELLE™ steam turbine (Unit 3), delivering 1,750 MW from the new EPR (Evolutionary Pressurized Reactor) from Areva. When commissioned in 2012, this will be the highest output in the world from a single turbine-generator set. Alstom will design, deliver and erect the complete turbine island, including the condensate extraction pumps, circulating water pumps and emergency diesel generator sets.

Flamanville 3
2,700 MW nuclear turbine island.
Flamanville started commercial operation in 1985 with two 1,350 MW units. The reactors are of the four-loop Areva “P4” type. Under a number of separate contracts, Alstom designed, delivered and erected the turbine-generators, and supplied the bulk of the turbine island mechanical and electrical auxiliaries, including condensers, feedwater reheaters, and condensate extraction and circulating water pumps. A power plant extension is now under construction. It will include one ARABELLE™ steam turbine (Unit 3), delivering 1,750 MW from the new EPR (Evolutionary Pressurized Reactor) from Areva. When commissioned in 2012, this will be the highest output in the world from a single turbine-generator set. Alstom will design, deliver and erect the complete turbine island, including the condensate extraction pumps, circulating water pumps and emergency diesel generator sets.

Forced Outage Rate

<table>
<thead>
<tr>
<th>Power Range</th>
<th>Alstom Data</th>
<th>NERC Benchmark</th>
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<tbody>
<tr>
<td>&lt; 1,000 MW</td>
<td>0.078%</td>
<td>0.023%</td>
</tr>
<tr>
<td>&gt; 1,000 MW</td>
<td>0.168%</td>
<td>0.068%</td>
</tr>
<tr>
<td>&gt; 1,500 MW</td>
<td>0.202%</td>
<td>0.078%</td>
</tr>
</tbody>
</table>

US average: 0.292%

Nuclear steam turbines
Chattanooga’s state-of-the-art manufacturing and engineering facility

Alstom will be shipping its high-technology components directly to its customers from Chattanooga and stepping-up its efforts on meeting the specific requirements of the North American power market. The site will serve both new and retrofit equipment markets in North America and will have the capacity to manufacture capital-intensive components with high-technology content for nuclear, coal and gas power plants. The new site will manufacture, assemble and test all products using the most up-to-date high precision machine-tools and other equipment available today. In fact, with Chattanooga, Alstom will be able to manufacture the largest turbines in the world and test them in its own rotor balancing facility – also the world’s largest.

Chattanooga’s situation on the Tennessee river gives it great access to an excellent network of road and rail links, and in particular to the US inland and coastal waterways system. This allows easier, more efficient shipping of large and heavy products. A special feature is our on-site barge dock with a lifting capacity of up to 1,000 tons – particularly suited to shipping large and heavy products.

UniStar

Alstom is to supply Baltimore-based UniStar Nuclear Energy, a joint venture between Constellation Energy and EDF, with a minimum of four turbine generators for a planned fleet of advanced-design nuclear power plants in the United States. The Chattanooga facility will play a key role in manufacturing, assembling, and delivering key components of steam turbine, generator and heat exchangers. The target for completion of the first of these nuclear power plants is 2015.
Expert services to optimise your power plant

Alstom has a complete range of services, from traditional spare parts supply and field service specialists to full maintenance of steam turbines for nuclear power plants. As an Original Equipment Manufacturer (OEM) of steam turbines for nuclear power plants, we are ideally placed to provide continuous plant improvement packages. These would include: performance and reliability upgrades, lifetime extensions and consultancy packages developed to meet the changing market requirements during a plant’s operational lifetime. Alstom Power’s 200 Local Service Centres, located in 70 countries, are there to provide local facilities and expertise directly to our customers, helping them to optimise their asset.

Long-term service contracts
Alstom’s long-term service contracts are flexible in scope of services and equipment covered as well as contract duration in order to meet your unique business requirements. Their modular structure allows tailor-made packages to be assembled based on the level of risk mitigation and guarantees required. Our service contracts ensure key requirements (depending upon scope of supply) are met:

- Predictable operation and maintenance costs
- Reliability and availability
- Heat rate and power output
- Environmentally sound products
- 24-hour / 7-day plant support
- Broad OEM experience.

Outage optimisation
Outage performance is paramount, since poor performance can lead to delays and increases the chance of a forced outage in the future. Equally, high-quality outages reduce the risk of breakdowns and can bring the plant online earlier. By working in advance of the outage season, we can plan your outage programme for optimal execution.

Upgrades
If the condition of a steam turbine requires major refurbishment, an upgrade offers a very economic opportunity to benefit from Alstom’s latest technology. Various upgrade packages have been developed to improve the performance of existing steam turbines manufactured by Alstom and other manufacturers. The upgrade project can be tailored to optimally meet your requirements. Increase of power output or thermal efficiency, or improvement of operational flexibility or reliability are usually the major aims of an upgrade project.

Lifetime extension
Alstom has service packages that use modern techniques to establish the residual life of turbine components. This, coupled with newer design techniques and modern materials, enables Alstom to extend plant life whilst incorporating performance and reliability upgrades. This ensures the plant remains competitive over longer periods at optimised costs.
We aim for the best utilisation of the customers’ investment, the earth’s materials and the fuel used, through efficiency, availability and cost reduction. The increased environmental concern applies to all types of power plants, new or existing. For fossil thermal plants, we develop cleaner combustion systems coupled with more efficient turbines and flue gas cleaning systems. CO$_2$-free nuclear power plants also benefit from our clean power solutions with, for example, our condensers and pumps minimizing auxiliary power and water consumption.

Alstom’s engineering and R&D workforce totals 5,500 people, of which 4,000 are in engineering and 1,500 in R&D in 22 R&D centres. There are 13 laboratories with dedicated infrastructure, equipment and testing facilities.

Alstom Power R&D policy takes a global approach, which has several benefits. First, it puts the work where the expertise is located. Second, it helps to nurture close contacts with universities and design institutes that can complement our in-house efforts. Third, it enables us to stay in touch with global customers’ expectations, anticipate their needs and lead the technology trends.

Alstom Power works with more than 30 universities worldwide. We establish close, long-term links with institutions and professors who are experts in fields that are important to us, for example, with MIT and Stanford Research Institute on CO$_2$, Grenoble and Lausanne universities on hydro turbines and fluid dynamics, Cologne’s DLR on combustion, and Oxford University on heat transfer, as well as with engineering institutes in China, India and Russia.

In the field of international collaboration, Alstom Power has played a leading role in establishing the European technology platform for zero emission fossil fuel power generation (ZEP).
A world leader in clean power generation

Alstom is a global leader in power generation and sets the benchmark for innovative and environmentally friendly technologies.

The company designs, manufactures and delivers state-of-the-art products and systems to the power generation nuclear and industrial markets. As a CO₂-free energy source, nuclear power contributes to the clean power solution. Our portfolio covers all plants (both existing and new ones), all energy sources (from fossil fuels like gas and coal to hydro, wind and nuclear), and all emissions (NOx, SOx, Mercury, CO₂ and particulate matter).

Our objective is to build the cleanest integrated power solutions for our customers. Alstom provides the conventional equipment for nuclear power plants that offers an attractive CO₂-free operation characteristic. For fossil-fueled thermal plants, we supply and integrate all components of a clean power system, from clean combustion boilers or gas turbines to air quality control and energy recovery systems. Alstom not only has extensive experience in retrofitting, upgrading and modernising existing power plant equipment, also boasts unrivalled expertise in project management for all types and sizes of power generation systems, including turnkey solutions.

Alstom’s unique offering brings real value to customers. With our innovative plant integration concept, we help operators to maximise their plant performance, while fully complying with environmental regulations and obligations.

Expertise in clean power solutions
Plant operators face multiple challenges in their efforts to make their plants more competitive, while complying with the different environmental regulations. Alstom is delivering clean power solutions now. As the uncontested leader in clean power generation technologies, we provide the cleanest integrated power solutions on the market.
Alstom offers the complete range of products designed to help power plants to either reduce pollutant and CO₂ emissions or to produce clean electricity from the outset. For example, we deliver new coal-fired power plants with an advanced supercritical design using proven clean combustion solutions that are integrated with state-of-the-art emission controls. Retrofitting plant components or upgrading the whole system similarly improves the thermal and environmental efficiency of existing power plants.

Investing in the future of clean power
Alstom is uniquely placed as a plant integrator and full-service provider to design and manufacture all the components of a clean power plant. Alstom also invests in the research and development of new environmentally friendly power solutions. Together with partners, universities and customers, we are working on collaborative projects to develop solutions for pre- and post-combustion CO₂ capture and oxy-firing. Alstom also supports the next nuclear reactors generation (GEN 4) through a continuous improvement of its power conversion systems.

A world leader
Alstom supplies major equipment for 25% of the world’s installed base, making us:

N°1 in installed turbines and generators for nuclear power plants
N°1 in turnkey power plants
N°1 in air quality control systems
N°1 in hydro turbines and generators
N°1 in the number of installed boilers worldwide
N°1 in steam turbine retrofit and integrated retrofit projects

Alstom is a global leader in power generation and sets the benchmark for innovative and environmentally friendly technologies.