

STEAM TURBINES

A FULL RANGE TO FIT YOUR NEEDS



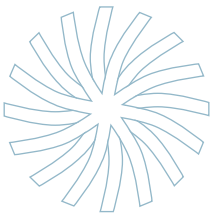
POWER

We are Shaping the future

ALSTOM

Alstom steam turbines

Leading the way in efficiency and reliability



“Dynamic” is the only way to describe the electricity market. Fast-growing demand in developing countries requires new power production capacity. Elsewhere, ageing fleets need to be replaced. Despite increased focus on renewables, thermal power plants continue to dominate electricity production – and will do so for many years to come. However, environmental concern will oblige thermal power plant operators to use the best available technology to conserve the Earth’s resources. The best Steam turbine technology is the obvious choice.

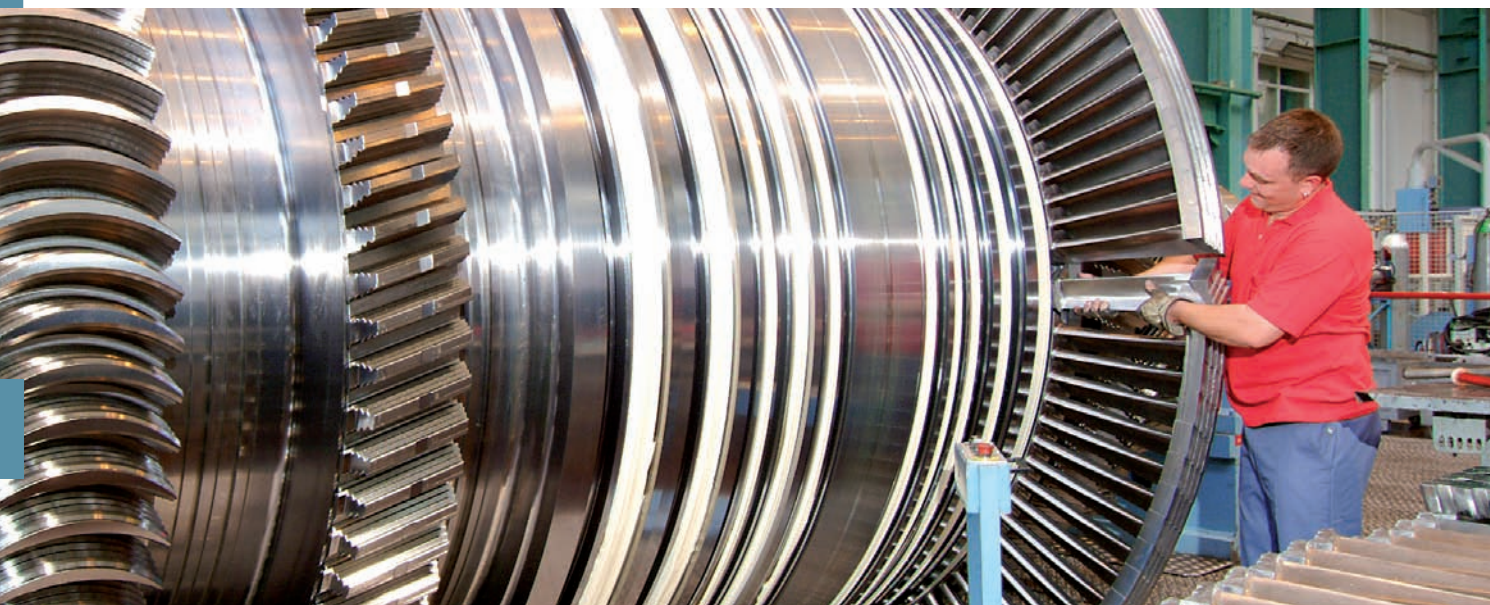
Alstom has been designing and building steam turbines for over 100 years. In that time, we have constantly driven their performance, efficiency and reliability. Today, Alstom offers a complete range of advanced, highly efficient and reliable steam turbine generator sets. They are designed for clean power production for all kinds of fossil applications up to 1,200 MW and up to 1,800 MW for nuclear plants, in 50 Hz and 60 Hz networks.



Alstom is a global leader in power generation, setting the benchmark for innovative technologies that provide clean and efficient power solutions for its customers.

With more than 25 per cent of the world’s installed power generation base Alstom designs, manufactures, supplies, installs and services the broadest range of systems for power generation and industrial markets, with a portfolio of products that extends across the entire energy value chain for all fuel types, from fossil, biomass to nuclear and renewables. Alstom can supply these products as single components or as complete turnkey power plants, which, through its Plant Integrator™ approach and smart grid solutions, are optimised to deliver maximum value for the customer throughout the lifetime of the plant.

Alstom’s specialists have developed extensive experience in engineering, procuring and constructing new plants as well as retrofitting, servicing and modernising existing power plants. Operating in more than 70 countries, Alstom is always close to the customer to ensure rapid response with the right level of service excellence.



Steam turbines: the benefits



Reliability and availability

- ✦ Outstanding reliability by using proven modules for any size and process.
- ✦ Proven design principles, even for most advanced steam parameters.
- ✦ Welded rotors – no rupture since introduction almost 80 years ago.
- ✦ Single bearing design for excellent and sustained rotor dynamics.
- ✦ Maintenance-friendly design for shorter outage times.
- ✦ Extended overhaul periods for higher availability.



Efficiency and performance

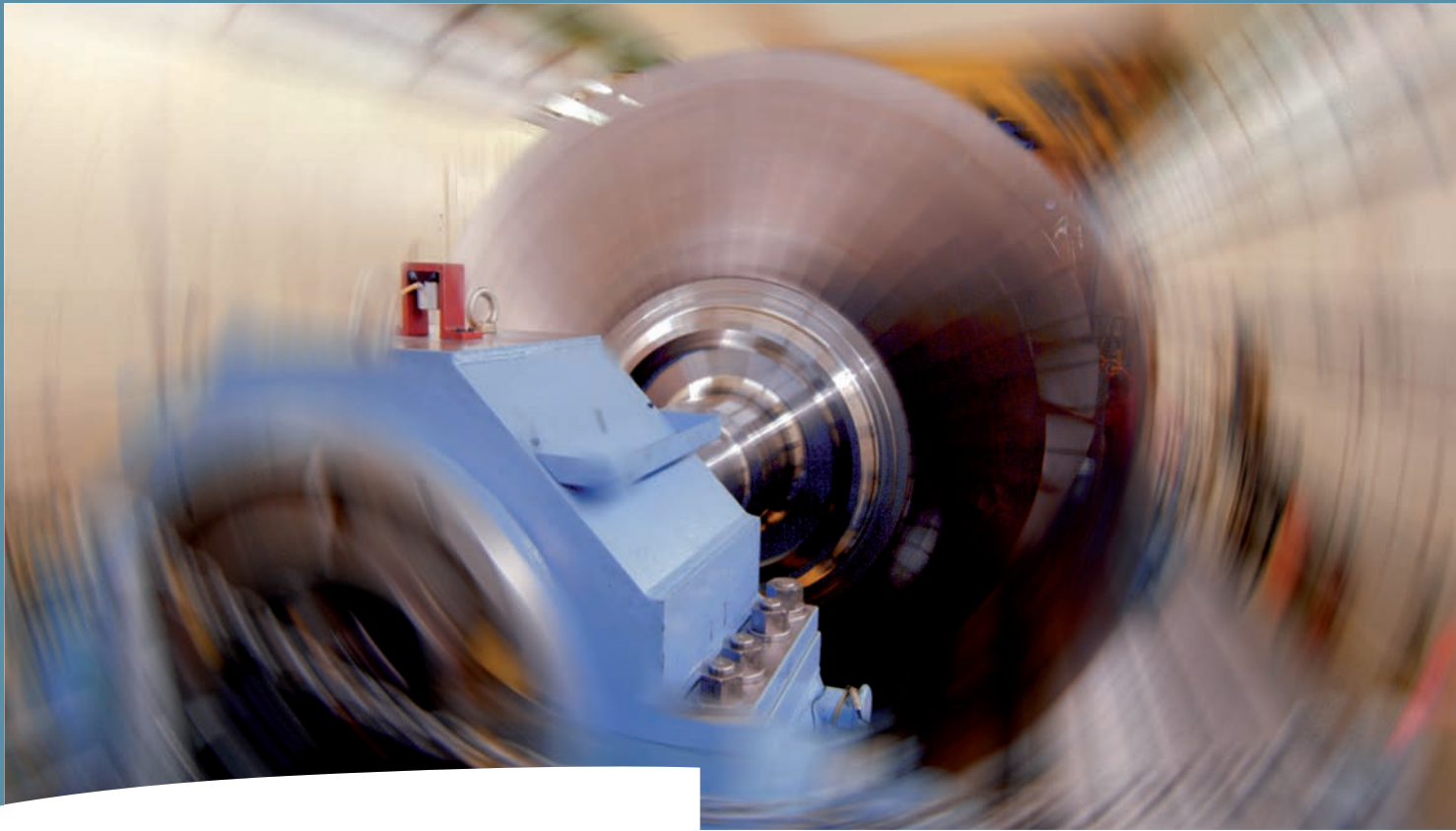
- ✦ Designed to adapt to the highest inlet steam parameters for the most advanced ultra-supercritical cycles.
- ✦ Project-specific steam path for optimal economic efficiency.
- ✦ Advanced 3-D blades and optimized flow path.
- ✦ A comprehensive portfolio of high-performance last stage blades to adapt to all unit sizes and cooling conditions in any climate.
- ✦ Shrink ring design in high-pressure turbines and optimised inner shell of the intermediate pressure turbine for thermal flexibility and sustained efficiency.
- ✦ Welded rotor for better thermal flexibility – faster to the grid and lower start-up costs.



Clean power

Less fuel consumption and lower emissions through:

- ✦ A design for the highest steam parameters that the materials sustain.
- ✦ Utmost exploitation of cooling conditions at the cold end.
- ✦ Long-term sustained efficiency through unique design features.
- ✦ Shorter start-up times through more flexible thermal design.



Technology you can trust

To date, Alstom has supplied steam turbines totalling almost 580 GW and its fleet has conquered about 23% of the world's installed steam turbine capacity.

Alstom is the European leader of large capacity ultra-supercritical units and builds the world's largest single-shaft steam turbine generator sets with a power output of more than 1,100 MW. The world's seven largest fossil units, each producing 1,300 MW in a cross-compound arrangement, were designed and built by Alstom.

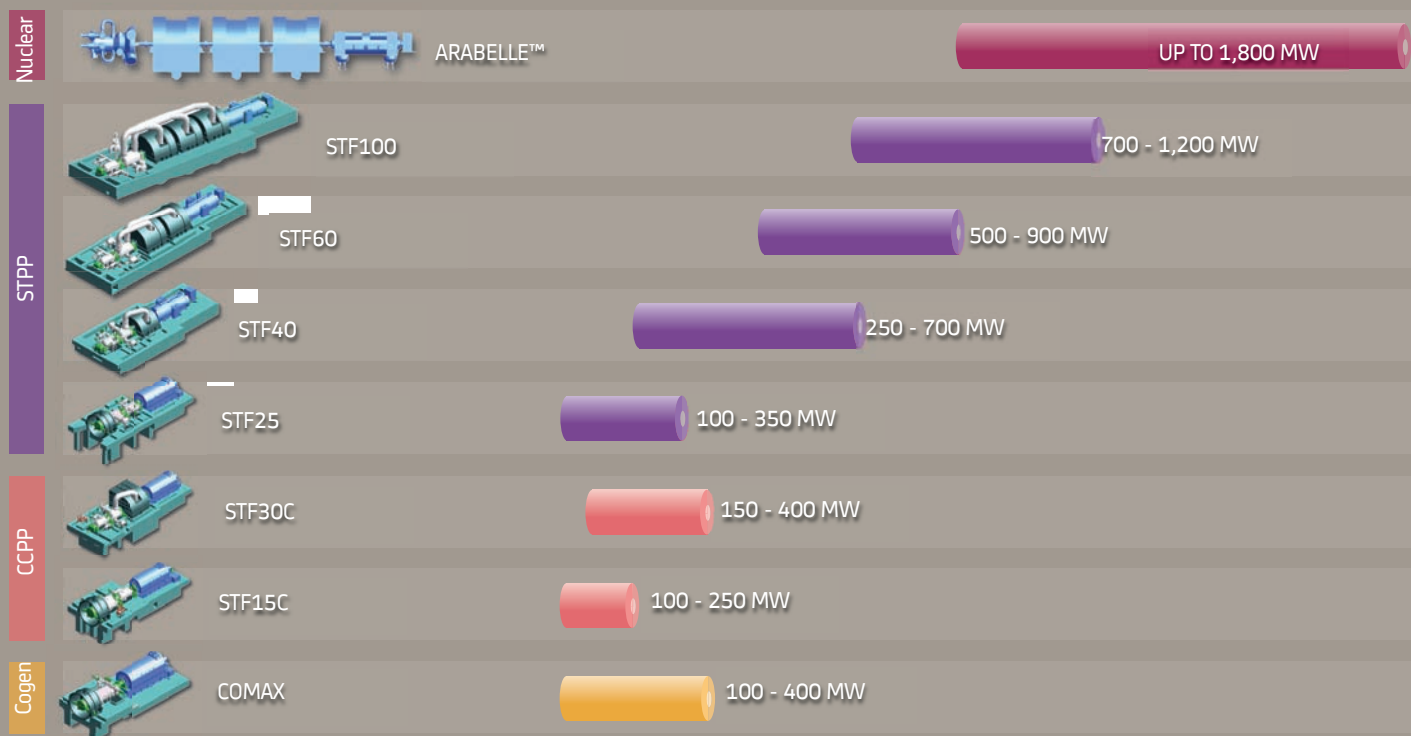
Alstom is also recognised as a leading supplier for steam turbine generator sets in combined cycle and cogeneration applications.

Over 30% of nuclear power plants feature Alstom steam turbine generator sets. The world's four largest operating nuclear units, with a capacity of 1,550 MW each, are ARABELLE™ steam turbines from Alstom. And the 1,750 MW unit capacity of the Alstom ARABELLE™ steam turbine combined with the Alstom GIGATOP 4-pole turbogenerator for Flamanville 3 in France set a new world record.

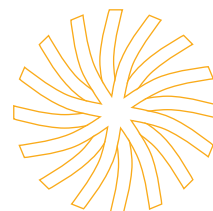
Flexibility to meet your needs – today and tomorrow

- ✦ In combined cycle plants with advanced gas turbines, the flexible thermal design of the Alstom steam turbine generator sets results in a highly efficient heat-recovery cycle and fast start-up.
- ✦ In fossil-fired steam plants, Alstom steam turbines drive efficiency improvements because they can cope with the highest ultra-supercritical steam parameters today's materials can deliver.
- ✦ In cogeneration plants, Alstom steam turbines enable highly flexible operation between power and heat demand and efficiently accommodate wide variations in process steam flows.
- ✦ The Alstom ARABELLE™ nuclear steam turbines fit any reactor type; its unique design and reliability provide optimum efficiency.

Thanks to this flexibility and robust design, Alstom steam turbines will continue to meet your needs even if your operational conditions change in the future.



Comprehensive portfolio on a proven modular design offering high value to our customer



A modular design for reliability and performance

Alstom steam turbines are configured from pre-engineered standard modules. This modular concept governs all engineering and manufacturing processes and results in the shortest possible erection and commissioning times, high reliability and optimum efficiency.

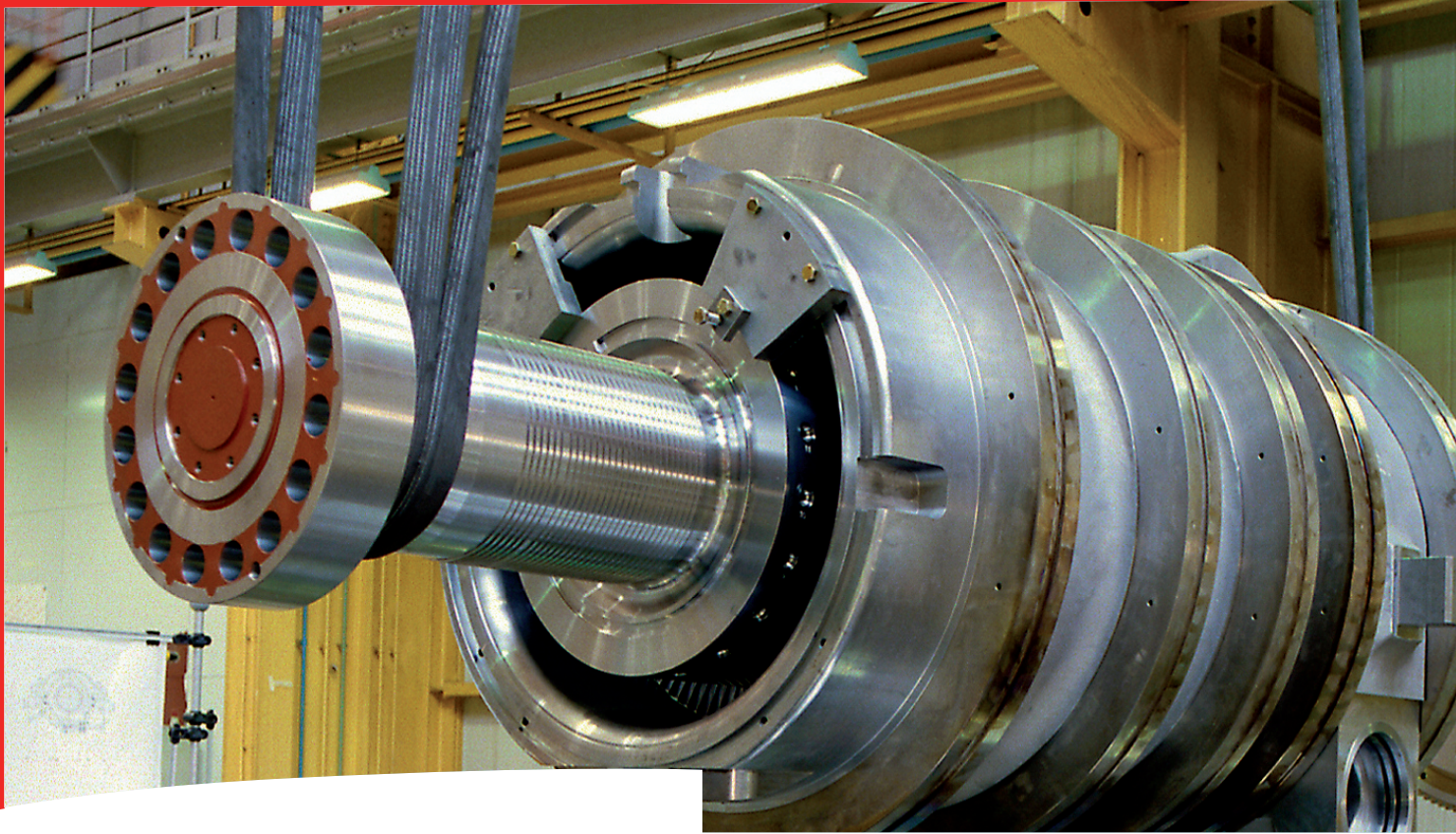
However, to maximise performance, the steam path is always adapted to the specific project requirements, and that includes material selection. This means that the materials for casings and rotors or rotor sections are selected according to the specific steam conditions.

Although steam turbine technology is often considered mature, improvements and new developments continue, with the aim of increasing plant efficiency and consequently reducing the environmental impact of thermal power production.

- ★ Efficiency is continuously being improved without compromising reliability and flexibility.
- ★ Mechanical integrity is a governing principle in all Alstom's steam turbine development programmes.
- ★ New features are developed from proven elements, and critical components introduced only after comprehensive model testing.

Operational feedback is systematically used to create customer value. And because of Alstom's modular turbine concept, such feedback benefits the entire product portfolio.

Alstom generally supplies the steam turbine together with the turbogenerator and the associated auxiliaries. That way, you get a matched system with high performance and optimised shaft dynamics.



Designed to last

Alstom steam turbines are designed for customers who operate in a competitive environment. They all have common features that directly yield competitive benefit – features that have been developed after years of intensive research and operational feedback.



Alstom's unique reheat turbines in fossil applications feature a separate, compact high-pressure turbine for highest efficiency and thermal flexibility.

Shrink ring design

The high-pressure steam turbine modules are of a unique double-shell design. Shrink rings hold the two halves of the inner shell together, forming a rotational-symmetrical inner casing with circumferential uniform mass distribution. This contributes to the unique thermal flexibility of the entire turbine.

Shrink rings also require less space than flanges with bolts. The HP turbine is therefore more compact and lighter. Both shells have comparatively small wall thicknesses, allowing fast steam temperature changes. The advantage

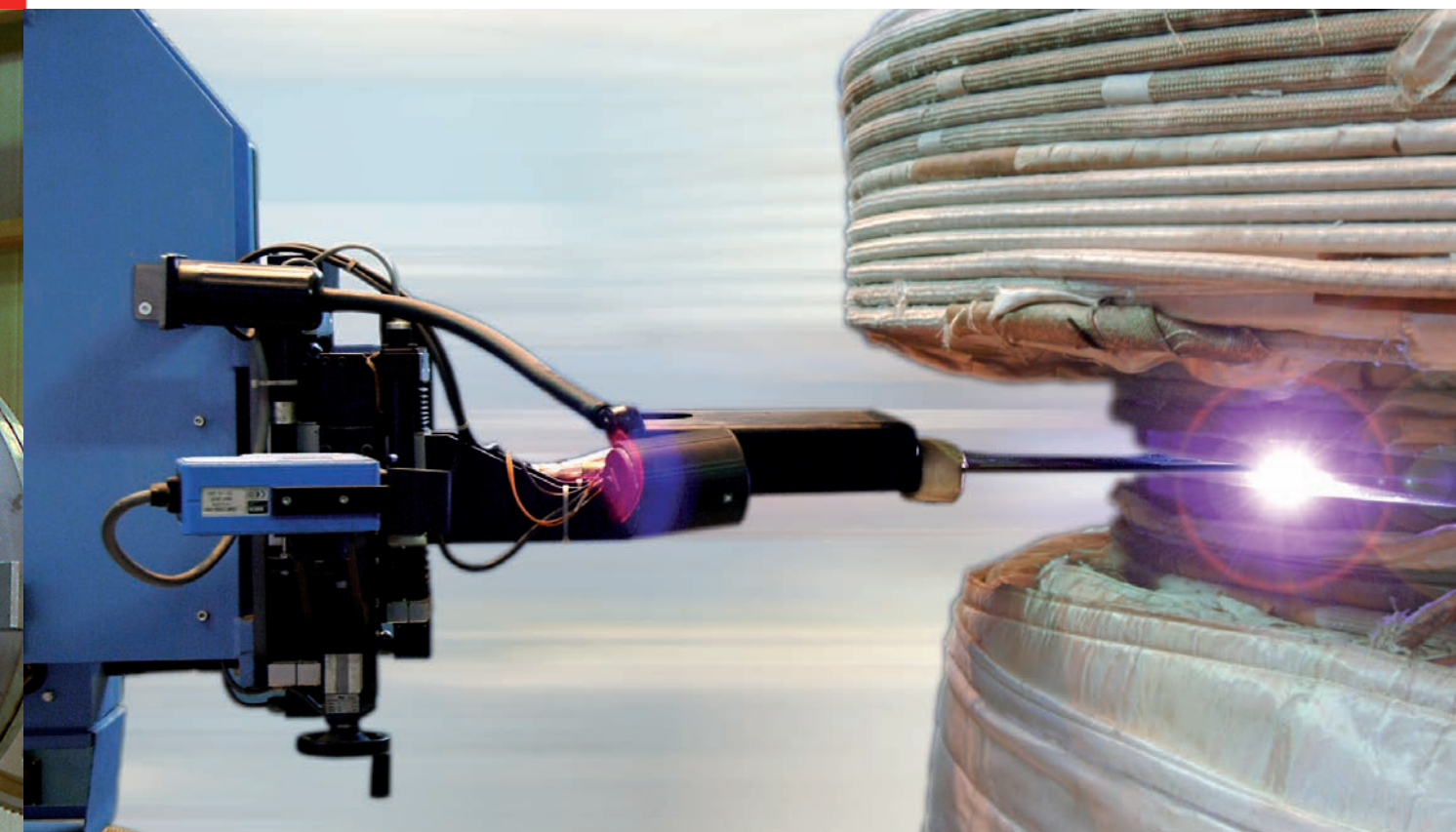
of this design is not only outstanding operational flexibility, but also long-term stable clearances and efficiencies.

Alstom's intermediate-pressure turbines are also of double shell design, which has been enhanced to minimise the casing distortions, particularly at very high temperature applications. This ensures sustained clearances and therefore efficiencies.

Based on Alstom's design principles, the turbine casings do not limit the turbine's thermal flexibility. No preheating before start-up is required. The rotor is the guiding component during start-up and load changes.

Welded HP and IP turbine rotors

Alstom large-diameter rotors are manufactured by welding together separate smaller forgings. The material



Alstom has by far the most experience
in welded rotor technology

is selected according to the mechanical requirements of the respective rotor section, with special advantages in case of very high temperature applications. A further gain lies in the fact that the stress levels of welded rotors are significantly lower compared to monoblock rotors – in particular during thermal transients. Welded rotors either allow faster start-up and load cycling or consume less life rate than monoblock rotors.

Welded LP turbine rotors

The small forging disks for Alstom welded rotors are manufactured with a high level of integrity before welding together into a large rotor. Large welded rotors invariably have a better metallurgical structure than equivalent monoblock rotors. Centre bores are not required with welded rotors and their size is not constrained by considerations of material properties.

The prime benefit is the high inherent safety of this design. No Alstom welded rotor has ever suffered rupture or similar failure. Alstom has by far the most experience in welded rotor technology (introduced in 1930).

Alstom low pressure turbine rotors are not subject to mechanical shrinkage stresses, as are rotors of shrunk-on disk design. The blade attachment integrity of Alstom rotors is far superior to that of monoblock designs. The material used is highly ductile low-alloyed steel. The combination of the materials and mechanical design eliminates critical conditions that can lead to stress corrosion cracking. The result is increased rotor lifetime. Turbine rotors are coupled with expansion sleeves instead of fitting bolts. The sleeves provide zero-clearance seat and yield better torque transmission, even in exceptional operating situations.

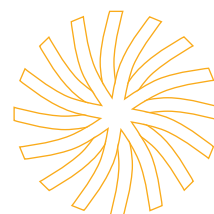
Single bearing design

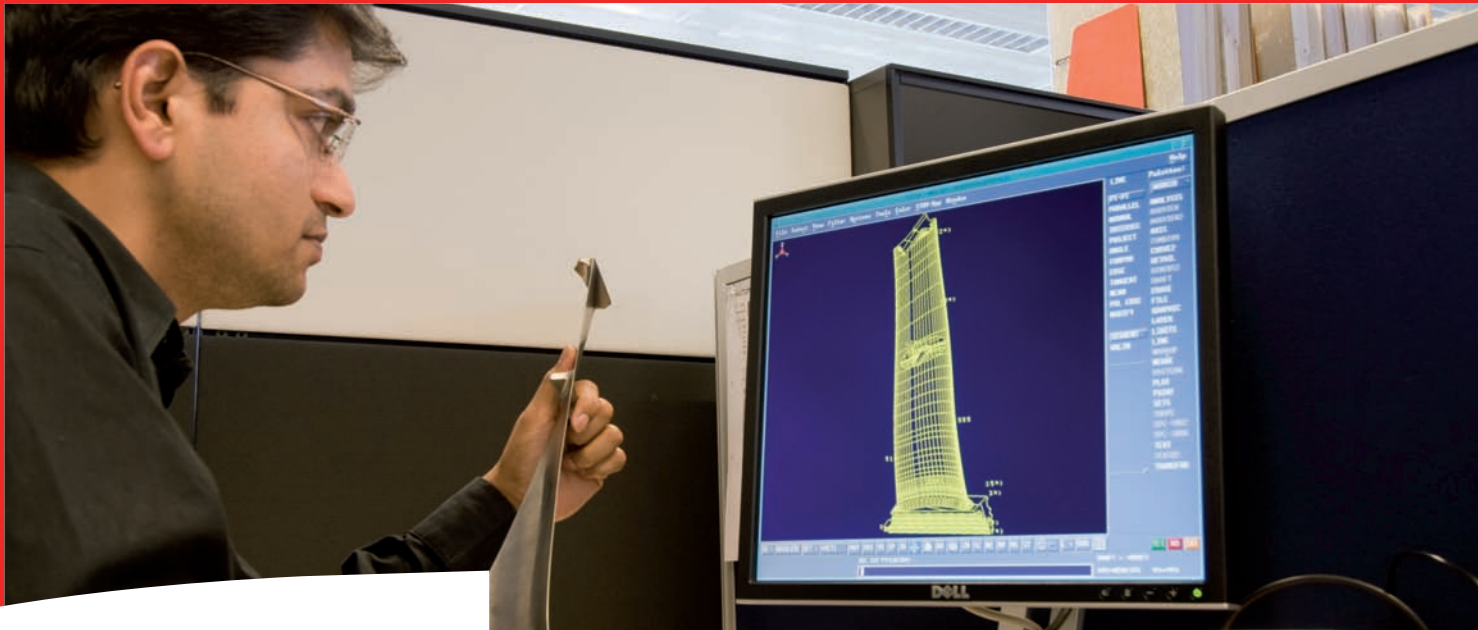
Alstom multiple-casing turbines have one single bearing between each turbine section. Load shifting between adjacent bearings is not possible. Problems with oil whip, foaming and vibration excitation through partially loaded bearings cannot occur. The result is increased turbine availability.

Shaft-driven main oil pump

Shaft-driven gear pumps supply the main lubrication oil. Gear pumps ensure turbine lubrication until the shaft comes to rest – even if DC emergency systems should fail.

Hence this principle contributes to the high operational safety of Alstom steam turbines.





Designed for efficiency

Alstom is constantly enhancing turbine efficiency and reliability. This also contributes to our commitment to clean power.

Large last stage blade



Advanced blading

In its over 100-year history, Alstom has always driven steam turbine efficiency, in reaction as well as in impulse technology. Today, Alstom steam turbines have blades with the most modern three-dimensional airfoil designs in both technologies, with special characteristics to achieve greatest performance. The impulse design is used in new nuclear units, whereas all new steam turbines in fossil applications are based on reaction technology.

So-called 'aft-loaded' profiles produce less turbulence and lower secondary flows. Enhanced blade hub and tip shapes ensure that the leakage flows merge smoothly with the main flow. This reduces flow disturbances and leads to the highest possible steam path efficiencies.

The Alstom single-piece blade design delivers high turbine efficiency combined with excellent mechanical integrity. It also raises availability throughout a prolonged turbine life.

LP large last stage blades

The large last stage blades of the LP turbines are a key feature for improved steam turbine efficiency. Alstom's LP turbine last stage blades can be selected based on the project-specific cold end conditions. For very large exhaust areas, Alstom employs titanium blades to optimise the aerodynamics without compromising mechanical integrity.

Single-piece blades for HP and IP turbines and the LP turbine front stages forming a prestressed rigid ring





Separate HP and IP turbine modules

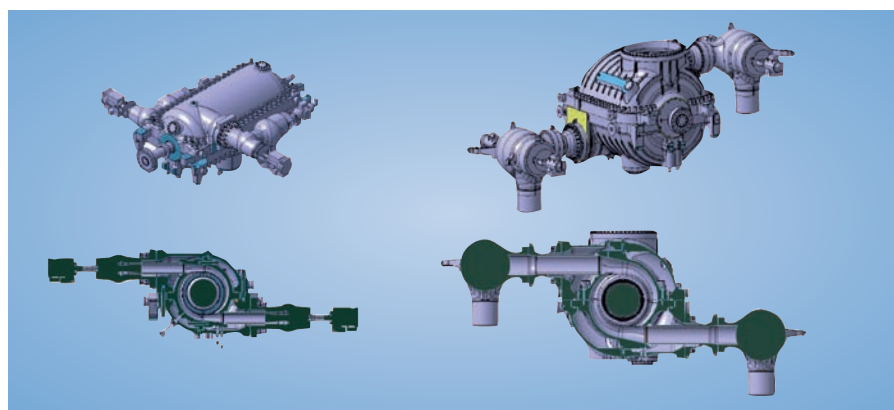
For reheat applications, Alstom turbines feature separate HP and IP modules. For outputs up to 350 MW, single-flow modules can be combined with single-flow low-pressure modules to form highly compact IP/LP turbines. Turbines up to 500 MW can be configured with single-flow IP modules. Above that, double-flow IP modules are used. The high power density of these cylinders, together with the compact single-bearing concept, leads to footprints no larger than those of combined HP/IP turbines. Simplicity, robustness, and higher, sustained efficiency are the main advantages of this concept.

Low admission losses

High-pressure turbines for sliding pressure operation and all intermediate-pressure turbines have one or two spiral-shaped inlet scrolls; all double-flow LP turbines are equipped with a single scroll. They help convert the steam's kinetic energy into mechanical energy with lower losses, contributing directly to higher overall turbine efficiency. This design is of particular advantage for high temperature applications. Optionally, HP turbines with inlet scrolls can be equipped with integrated second main steam injection bypassing the first stages by means of integrated overload

valves. This method provides additional load reserve at constant pressure.

For hybrid pressure operation with a wide constant pressure range, mainly used in subcritical applications, Alstom offers an inlet module with a control stage that efficiently allows partial arc admission. The control wheel is formed out of a solid ring and welded onto the rotor. The resulting absence of mechanical fixation means high mechanical integrity, robustness, and a long maintenance-free component lifetime.



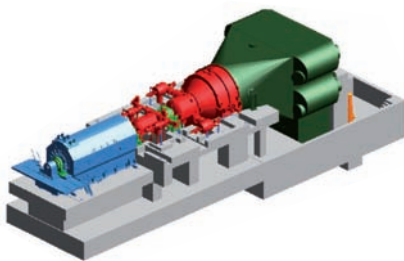
High pressure and intermediate pressure turbines with inlet scrolls for smooth circumferential steam admission



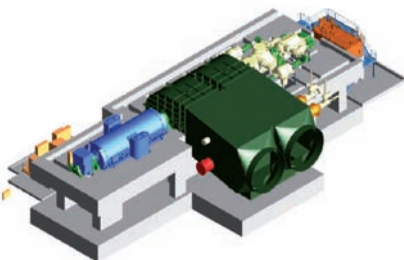
Completely shop-assembled 200 MW
cogeneration steam turbine at site installation

Designed to reduce costs

Alstom steam turbines are designed to provide maximum availability for the customer. Special features minimise non-operating hours during the entire lifetime – starting from the day of commissioning.



Compact reheat turbine generator
set on low level foundation



Axial and lateral exhaust options for lower initial plant cost

Alstom steam turbines can be arranged on the floor level, so the condenser can be placed in the axial direction or at the side of the steam turbine. As no turbine table is required, the foundation can be kept very simple. In addition, the size of the turbine hall can be significantly reduced – which also simplifies such things as piping, HVAC, stairways, intermediate floors, etc. This significantly reduces initial costs.

Compact reheat steam turbine generator sets up to 350 MW with axial LP exhaust – saving plant first cost.

The unique Alstom lateral LP exhaust design has been working successfully for many years; it is applied not only to single and double flow exhausts, but also to multiple-flow arrangements.

Short erection time

Alstom steam turbines are fully assembled on leaving the factory. Site assembly or opening for commissioning is not necessary. The only exceptions are large LP turbines that cannot be transported in one piece to the country of destination. In such cases, their outer casing parts and fully bladed inner casings and rotors are shipped separately and assembled on site. Auxiliary equipment, such as the control oil and lube oil skids, is assembled before shipping. Pipes and supports are pre-manufactured and shipped ready for installation. Electronic control cubicles are completely wired and tested. On site, erection is greatly simplified by Alstom's single-bearing concept, which also includes the large turbogenerators. Moreover, the axial/lateral LP exhaust design enables parallel erection of the steam turbine generator set and the condenser. This significantly saves erection time. These features directly contribute to customer profit by shortening the project cycle time, lowering initial costs and reducing the construction risks.



Easy inspections

The first and last rows of each turbine module are accessible for visual inspection by boroscopic instruments. Disassembling the turbine cylinders is only required for major inspections.

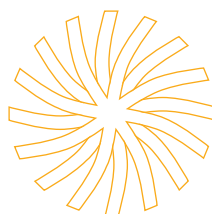
Opening or closing the HP inner casing is straightforward and can be done at site easily. Shrink rings are removed or mounted by heating with an annular gas burner. Less than half the time is required compared to opening tension bolts.

When rotor elements need to be removed, their separation from the shaftline is facilitated by the expansion sleeve coupling, which is easy to dismantle, even after abnormal torque transmission. And Alstom's bearing design makes shaft re-alignment easy.

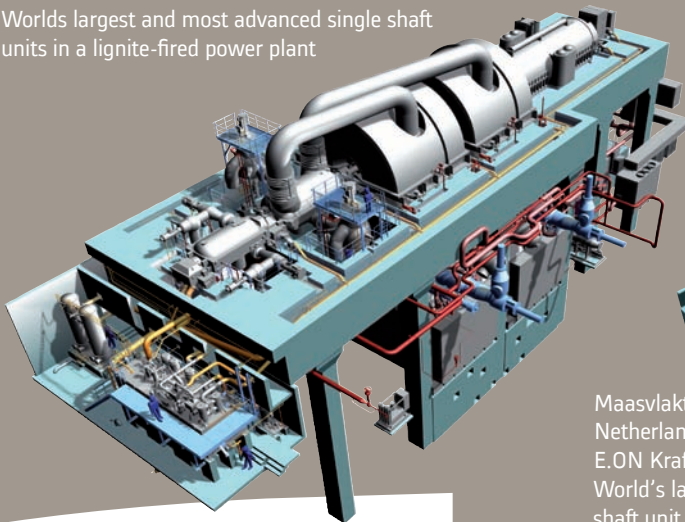
All these features result in shorter overhaul times, so that the unit can get quickly back on line.

Few overhauls

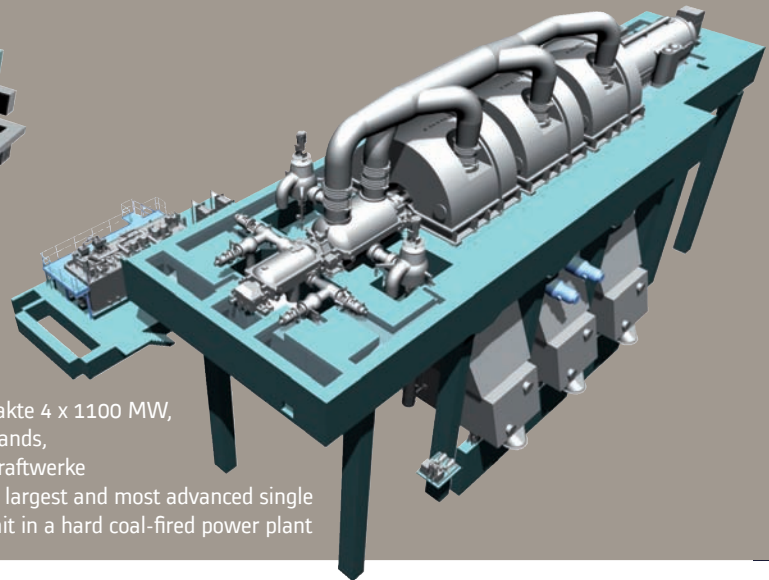
Alstom steam turbines need few overhauls; they can be timed to match the required gas turbine or boiler or generator maintenance periods. The robust design allows extended periods for major overhauls. Medium inspections are usually performed every 25,000 EOH. However, there is a trend to condition-oriented and proactive maintenance instead of acting based on fixed time intervals. Thanks to the maintenance-friendly design, the easy accessibility and modern tools, the outage times are relatively short, which further raises availability.



Neurath 2 x 1100 MW, Germany
RWE Power
World's largest and most advanced single shaft units in a lignite-fired power plant



Maasvlakte 4 x 1100 MW,
Netherlands,
E.ON Kraftwerke
World's largest and most advanced single shaft unit in a hard coal-fired power plant



Alstom steam turbines in action

Neurath / GERMANY Maasvlakte / NETHERLANDS

STF100 steam turbine and GIGATOP 2-pole turbogenerator in STPPs

With its 2 x 1100 MW steam power plant at Neurath, Germany, RWE has set a new size and efficiency benchmark for lignite-fired power plants. Alstom's scope includes the steam turbine generator sets, condenser and the power plant engineering.

Maasvlakte in the Netherlands is one of a 4 x 1100 MW convoy E.ON Kraftwerke placed with Alstom. It's another new benchmark for hard coal-fired power plants. Alstom's scope includes the steam turbine generator set, the condenser and the boiler feed pump turbine (1 x 100%). It is the largest single-shaft full-speed unit worldwide. Because unit output exceeds 1100 MW, the Alstom GIGATOP 2-pole turbogenerator is designed for 1400 MVA – a new milestone in 2-pole technology.

The steam turbine and turbogenerator designs of these units are evolutionary developments, based on the Lippendorf units in Germany with 2 x 930 MW, which have been operating successfully since 1999/2000.

Front Range / USA

STF30C steam turbine 2 x 230 MW and TOPAIR turbogenerator in a CCPP

Alstom developed its products to meet the needs of large combined cycle power plants using air-cooled condensers. The STF30C with the TOPAIR generator was the ideal match. Alstom's unique lateral exhaust reduced cost and improved efficiency by keeping the foundation height low and exhaust ducts to the ACC short. Standardised modules led to fast delivery, and the customised steam path optimised performance.



Sohar / OMAN

COMAX-1 steam turbine 220 MW and TOPAIR turbogenerator in a cogeneration plant

SOHAR is an example of the new generation of large cogeneration plants where electrical generation is as important as steam production. Alstom was contracted to provide a single casing, single flow (COMAX-1) steam turbine coupled with a TOPAIR generator to meet the plant's operating needs. The COMAX-1's flexible and large extraction capability met the steam needs of the desalination plant while providing efficient electrical generating capacity. In addition, Alstom's ability to provide this large industrial turbine in an assembled package reduced cost, assembly time and risk.



Best-of-Class R&D Capabilities

Alstom's R&D is market and customer oriented and focuses on creating innovative technologies to apply at all stages of our products' life cycles.

We aim for the best utilisation of the customers' investment, through efficiency, availability and cost reduction. Increasing environmental concerns lead Alstom to focus on minimising CO₂ emissions through the development of technologies that can be applied in new and retrofit installations.

Alstom Power's engineering and R&D workforce totals 5,500 people, of which 4,000 are in engineering and 1,500 in R&D in over 20 R&D centres. There are more than 10 laboratories with dedicated infrastructure, equipment and testing facilities.

Alstom Power's R&D policy takes a global approach which has several benefits. First, it puts the work where the expertise is located. Secondly, it helps to nurture close contacts with universities and design institutes that can complement our in-house efforts. Thirdly, it enables Alstom teams 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. Long-term links have been established with institu-

tions such as the Massachusetts Institute of Technology (MIT) and Stanford Research Institute on CO₂, Grenoble and Lausanne universities on hydro turbines, Cologne's Deutsches Zentrum für Luft- und Raumfahrt (DLR) on combustion, 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).



LP rotor in model test turbine
Verification of calculation results, a central part of Alstom R&D



Service during operation

Extensive service experience

Alstom has a full range of services from traditional spare parts supply, through performance upgrades, plant optimisation, and lifetime extensions, to full operation and maintenance of steam turbine power plants. The resulting efficiency improvements reduce emissions and lessen the impact on the environment. Through our 60 Local Service Centres in 70 countries, you have direct access to Alstom Power Thermal Services' local facilities and expertise. They offer remote, comprehensive technical support for steam turbine generator units.

Plant optimisation: ECO|RAM™ has been developed to systematically identify plant improvement potential. The result is a portfolio of improvement measures for plant equipment, operation and maintenance. The STEP|x™ set of improvement tools analyses possibilities to increase plant capacity, availability and lifetime. Upgrades offer a very economic opportunity to benefit from Alstom's latest technology. Various upgrade packages have been developed to match your operating strategy. Increased power output, improved operational flexibility or reliability are the major aims.

Alstom has service packages to establish the residual life of the salient turbine components. This enables Alstom to extend plant life while incorporating upgrades to improve performance, ensuring that a plant remains competitive longer with optimised costs.

Alstom's long-term service contracts will meet your unique requirements. You can choose from traditional Purchase Order Contracts, Service Agreements, and Operations and Maintenance Contracts.

Plant Integrator™ – creating customer value

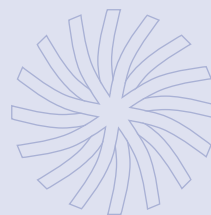
Alstom's **Plant Integrator™** approach is based on the belief that the "Net Present Value" (NPV) of the power plant over its lifetime is the best way to measure the value of a given plant construction project.

To evaluate and calculate the value, NPV calculation methods and tools are used.

Alstom has identified six key areas to increase the NPV:

- ✦ Investment
- ✦ Lead-time
- ✦ Performance
- ✦ Availability & operational flexibility
- ✦ Retrofit
- ✦ Life extension

Other areas that can sometimes matter are considered as well, e.g. the compliance with or anticipation of environmental regulations; or the ability to accept fuel flexibility. Nevertheless these conditions can always be translated into one or several of the above-mentioned six areas of value.





Lignite-fired power plant in Lippendorf, Germany, 2 x 930 MW
– successful operation since 1999/2000, Vattenfall

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 (gas, coal, wind and hydro power plants) and industrial markets. In addition, Alstom provides the conventional equipment for nuclear power plants.

Our objective is to build the cleanest integrated power solutions for our customers. We supply and integrate all components of a clean power system, from boilers to air quality control and energy recovery systems. Alstom not only has extensive experience in retrofitting, upgrading and modernising existing power plant equipment, but 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. They cover all plants (both existing and new ones), all energy sources (from fossil fuels to hydro and nuclear), and all emissions (NO_x, SO_x, Mercury, particulate matter).

Alstom offers the complete range of products designed to help power plants to either reduce pollutants 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 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 oxy-firing and post-combustion CO₂ capture.

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