Managing the balance between energy production and consumption has become an issue of growing importance in order to guarantee the stability of electrical networks. Pumped storage hydroelectricity is the only economic and flexible means of storing grid scale amounts of excess energy, allowing power plants dispatchers to successfully manage that balancing act. This is becoming even more important as more and more countries are increasing their nuclear power generation capacities and ramping up their power generation from intermittent renewables such as Wind and Solar.

In pumped storage plants, Pump turbines transfer water to a high storage reservoir during off-peak hours, thereby levelling out the daily generated load. The energy used for pumping the water is derived from other energy sources, such as nuclear, fossil and renewable power plants, whose power output cannot be adjusted to follow load fluctuations. The stored water can then be used for hydroelectric power generation to cover temporary peaks in demand.

The advantage of this technology is that it can come online very quickly, making it a useful tool to balance the varying electricity demand from consumers or unplanned outages of other power plants. Today there are over 130 GW of pumped storage in operation around the world, representing approximately 3% of instantaneous global generating capacity. In recent years, the profitability of pumped storage plants has increased as a consequence of increased price volatility on electricity spot markets.

As the world leader in pumped storage Alstom provides a complete range of pumped storage electromechanical equipment. This includes Pump turbines, motor-generators, control systems and optimised hydro-mechanical and balance of plant equipment. Depending on the customer preference, these can be supplied either separately or as an integrated turnkey plant.

In the latter case, specialised Alstom teams have developed specific skills for optimising the complete plant configuration so that the highest global water-to-wire performance is achieved.
Meeting all market needs

Alstom has been providing Pump turbines for over 50 years and has supplied a total of 140 Pump turbine units to date. Between 1953 and 1960, orders were predominantly for low head units. More recent market trends indicate the need for high-speed Pump turbines at very high heads. In response to this, Alstom has invested heavily in Pump turbine R&D. In 2008, it extended its turbine hydraulic scale model test laboratory in Grenoble, France, to have two dedicated Pump turbine test-rigs, thus increasing the number of test-rigs in this facility by six and doubling its overall test capacity.

Alstom’s complete pump turbine range

Alstom provides Pump turbines adapted to the specific characteristics of each pumped storage plant. In order to cover the complete head range (from 10 m to 1200 m), axial, mixed or centrifugal flow runners are used.

Alstom has built up an extensive Pump turbine hydraulic design portfolio, with more than 50 Pump turbine prototypes. Between 2000 and 2009 alone, Alstom commissioned 14 major Pump turbine projects, and since then has been working on an increasing number of new projects. This gives Alstom the strongest market base for designing optimised Pump turbines for new projects.

For each project, a dedicated hydraulic team from the Alstom Global Technology Centre uses its state-of-the-art computational fluid dynamics (CFD) tools and laboratory tests, to simulate how the life-size turbine will operate in order to optimise its hydraulic performance. Particular attention is given to power output, efficiency, stability, rotor-stator interactions and absence of cavitation. Mechanical constraints are taken into account by verifying all static and dynamic characteristics using Finite Element Method modelling (FEM) tools.

After this, scale model tests are carried out on one of the two dedicated Pump turbine test-rigs in the scale model test laboratory. The high accuracy level of the laboratory tests (between 0.2% and 0.3%) ensures at an early project stage that the final Pump turbine will meet its performance requirements.

Plant Integrator™ – optimising the value chain

The Plant Integrator™ approach creates real value for our customers by optimising the entire value chain and the overall plant performance.

This approach goes beyond the typical product compilation simply aimed at reducing costs. As an OEM and O&M provider, Alstom has a unique perspective that allows the analysis of the whole plant and the full lifecycle as an integrated system. Using proven models and established benchmarks, specific investment costs can be understood in their true context. Customers benefit from a greater range of options to determine the solutions that are best suited to their needs. These help them achieve their business objectives and consequently, better serve their markets.

Key benefits

ENERGY STORAGE FOR GRID REGULATION
As the only solution for efficiently storing large amounts of energy, pumped storage power plant act as a quick response for peak load energy supply.

ANCILLARY SERVICES
Pumped storage technology provides network frequency and voltage regulation, reserve capacity, black start capabilities, as well as reactive power production.

INCREASED PLANT EFFICIENCY
Pumped storage technology increases profitability for plant owners in volatile electricity spot markets and allows optimisation of global operations of power plant fleets and electrical network infrastructures.

HIGHEST GLOBAL CYCLE EFFICIENCY
With approximately 80% efficiency pumped storage plants have the highest global cycle efficiency compared to other power plants.

ENVIRONMENTALLY FRIENDLY
Pump turbines have a positive environmental impact by enabling increased use of renewable energy sources.

Whether plant owners require a new facility, or are simply looking to upgrade or renew an existing installation, Alstom has the experience, know-how and mix of technologies to provide the right solution.
Single-stage or double-stage regulated
to best suite site conditions

From 10 m head to 1200 m head
Alstom has a solution to maximise
overall plant performance.

Recent developments have focused on enhancing the perfor-
mance, economy and reliability of these pumped storage
plants:
- single-stage Pump turbine technology has been expanded to-
ward double-stage and multi-stage Pump turbines for higher
head units, while maintaining a compact design in all configu-
trations.
- in reply to specific maintenance requirements and to optimise
the civil engineering costs, several Pumped storage plant
configurations are possible, allowing runner dismantling from
above, below or between the turbine and the generator thanks
to the use of an intermediary dismountable shaft.
- in addition to traditional oil lubricated white metal coated
bearings, Alstom has developed several specific bearings,
including self-pumping and water lubricated bearings.
- different types of governing control system configurations are
possible, either using an actuating ring to control all synchro-
nized wicket gates, or using individually actuated wicket gates
to optimise plant stability at start-up.
- depending on the head and customer preferences, a selection
of inlet valves are available including butterfly valves, spherical
valves or ring gates.

in order to reduce costs and to limit power input at start-up
in pumping mode, a Static Frequency Converter (SFC) or the
back-to-back method are typically used, combined with dewater-
ing of the runner.

For projects with very high heads, between 700 m and 1200 m,
multistage Pump turbines are needed in order to ensure good
hydraulic efficiency and minimise stress and vibrations incurred
by the turbine components. One typical limitation of these
multi-stage Pump turbines is that their power output cannot be
adjusted due to the absence of adjustable wicket gates on the
lower stages. In order to overcome this limitation, Alstom has
developed a unique solution consisting of a double-stage Pump
turbine equipped with two adjustable distributors, one for each
runner. These units can also be dewatered at start up to reduce
the input power. These double-stage regulated Pump turbines
combine the advantages of single
and multi-stage Pump turbines and are characterised by:
- adjustable power output
- better runner efficiency than with single-stage high heads, due
to head sharing between runners
- lower vibration than with single-stage high heads
- lower pressure pulsations
- higher mechanical stiffness
- better stability than with single-stage high heads
- the shaft crossing the draft tube improves part-load operation
- smoother transients with better intrinsic stability at start-up
- reduced civil engineering costs as the unit is more compact
and its submergence can be reduced.

Single-stage centrifugal units (< 700 m)
As most of the Pump turbine projects concern sites with 60 m to 700 m heads, the majority of Alstom’s pumped storage
references use reversible single-stage centrifugal units.

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Double- and multi-stage centrifugal units (> 700 m)
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- the shaft crossing the draft tube improves part-load operation
- smoother transients with better intrinsic stability at start-up
- reduced civil engineering costs as the unit is more compact
and its submergence can be reduced.

In 2006, Alstom supplied the biggest ever double-stage Pump
turbine built in the world, for the Yang Yang pumped storage
plant in South Korea. The four units, which are equipped with
two adjustable distributors, were built for a head of 798 m and
a power level of 4 x 258 MW.
Our outstanding market recognition is the result of sustained R&D efforts that have led to continuous technology improvements. These constitute the cornerstones that over several decades guarantee the high availability and stability of Alstom’s motor-generators. These units are subjected to numerous thermal cycles and high centrifugal forces, and need to withstand potential fault disturbances such as short circuits. In reply to these design requirements, particularly important for peak-load units, Alstom’s motor-generator main features include structural design with oblique elements, state-of-the-art thrust bearings, permanently pre-stressed stator core, Vacuum Pressure Impregnation (VPI) insulation system, self-ventilated rotor rim (standard or high speed design) and bent pole coils (for easier assembly & better surface cooling).

Oblique elements

Oblique elements are designed to meet motor-generator requirements like roundness, concentricity and stability, in all operating conditions. The oblique element stator frame provides a rigid connection against eccentric displacement but allows free concentric thermal expansion. This arrangement also avoids buckling of stator laminations, which occurs in rigid frames with non-flexible foundation connections. In addition, the connection to the base plates is totally maintenance-free since no sliding pads are necessary with oblique elements.

Thrust bearing pad membrane technology

The thrust bearing is a critical component of large pumped storage plants because it supports heavy weights and operates at high speeds in two directions (pumping and generating mode). Hydrodynamic thrust bearings in pumped storage units operate with a very thin layer of lubricating oil. In order to ensure continuous lubrication of the thrust bearing pads, Alstom has developed the membrane technology, which acts as a self-regulating mechanism to carry the bearing pads. In fact, the bearing pads are positioned on oil-filled steel membranes that are hydraulically linked to one another to always guarantee equal oil pressure under each membrane. This enables the system to self adjust an equal load distribution on the thrust pads. It does this in spite of deformations in the supporting frame or thrust loading conditions such as transient operation, shaft line deflection and shaft line misalignment. One of the main advantages of this unique membrane technology is that it helps to reduce friction losses in the thrust bearings. In fact it makes it possible to work at higher specific pressures on the pads, therefore minimising the bearing external diameter. A second advantage is that this system is faster to install on site as it is self-adjusting. Finally, by measuring the membrane oil pressure, it is possible to determine the hydraulic axial load on the shaft line and to carry out turbine condition monitoring.

Permanently pre-stressed stator core

Alstom’s stator core lamination pressing system is specially designed for units with high load cycles such as pumped storage, which experience frequent starts and stops with high thermal expansion. The clamping bolts are positioned in the stator yoke and ensure high, constant distribution of the stator core pressing. Spring elements compensate any potential settling of the stator core in order to maintain the pre-stress in the stator core over long service periods.

Vacuum Pressure Insulation system

The reliability of the stator winding is determined primarily by the quality of its insulation. Alstom has been using the Micadur® insulation system for more than 40 years. Additional research has led to further improvements to this system, providing excellent results on units even under severe conditions. To ensure permanent thermal and mechanical coupling between the stator bar surface and the stator core, the straight portions are supplied with “roundpacking”, consisting of a double-folded conductive polyester foil filled with a curable rubber compound. This system also ensures excellent grounding after installation due to the gap-free installation.

Bent pole coils

In bent pole coils, the centrifugal force of the field coil is perpendicular to the supporting surface of the insulation frame, between the pole coil and the pole shoe. This design concept, which eliminates the V-blocks between poles, makes the assembly easier and provides an increased pole coil cooling surface.

In the last 50 years, Alstom has supplied more than 300 motor-generators for pumped storage plants worldwide.
Alstom has a strong position in the field of variable speed pumped storage, gained through early R&D initiatives. This key expertise has resulted in the signing of significant contracts such as Linthal 2015 for 4 x 250 MW units and Nant de Drance for 6 x 157 MW units, both in Switzerland.

NANT DE DRANCE
Switzerland

Managed by Nant de Drance SA, with partners Alpiq, the national railway company Swiss Federal Railways (SBB) and the FMV (Forces Motrices Valaisannes), the Nant de Drance hydropower station is expected to generate 942 MW of electric power upon completion, corresponding to the total peak power demand of the Swiss Federal Railways.

Kraftwerk Linth-Limmern AG (KLL) is a partnership between the Glarus cantonal authority and Aspo AG. In 2009, KLL decided to extend its power station and has granted Alstom a contract to provide four new 250 MW variable speed pump turbine and motor generator units, boosting the output of the plant from 450 MW to 1450 MW. This will help meeting the peak power demand and helping to further develop the low carbon power generation of Switzerland.

As a result, Alstom’s variable speed pumped storage plants benefit from high levels of additional flexibility including:

- regulation of the amount of energy absorbed in pumping mode. This facilitates energy storage when power levels available on the network are low, reduces the number of starts and stops, and allows the sell of grid regulation service (network frequency and voltage) while in pumping mode.
- operating closer to the turbines optimal efficiency point, which results in a significant increase in global plant efficiency.
- smoother operation (for example at partial load), elimination of operation modes prone to hydraulic instability or cavitation. This results in improved reliability, reduced maintenance and increased lifetime. It also results in a reduction in the Pump turbine submergence level, reducing civil engineering costs.
- operating over a wider head range, increasing the availability of the plant. Installation of pumped storage plants on sites characterised by wide head variations, increases the partial load operation range to 33% of rated power in turbine mode and thus increases the generation flexibility.
- instantaneous power output adjustment help to rectify sudden voltage disruptions/variations caused by network problems. These benefits result in improved profitability for pumped storage plant owners, and allow network operators to improve the reliability of the grid as well as the quality of the power supplied to end consumers.

Latest innovation for highest flexibility

Unlike conventional hydropower plants, variable speed pumped storage plants use asynchronous motor-generators that allow the Pump turbine rotation speed to be adjusted.

Project highlights worldwide

Alstom has installed pumped storage plants all over the world. No wonder then the most prestigious, biggest and complex projects in the world rely on Alstom technology.

Switzerland

Linthal/Linthal 2015 – new: 4 x 250 MW variable speed turbine/generator units and VSI
Nant de Drance – new: 6 x 157 MW variable speed turbine/generator units and VSI
Grimsel – new: 4 x 90 MW generators, 750 rpm

Spain

Cruachan – new: 4 x 316 MW, turbine/generator units

South Korea

Yechon – new: 2 x 508 MW turbine/generator units, turbine power plant
Yang Yang – new: 4 x 250 MW double-stage regulated turbine/generator units, electrical & mechanical auxiliaries, control system

China

Yinjiang – 4 x 300 MW turbine/generator units, electrical & mechanical auxiliaries
Pushiha – 4 x 300 MW turbine/generator units, electrical & mechanical auxiliaries
Hukou – 4 x 300 MW turbine/generator units, electrical & mechanical auxiliaries
Huainan – 8 x 300 MW turbine/generator units, electrical & mechanical auxiliaries
Bailiang – 4 x 300 MW turbine/generator units, balance of plant, control system
Baoquan – 8 x 306 MW turbine/generator units, balance of plant, control system
Zangshewan – 4 x 255 MW turbines, control system
Shhe – new: 2 x 51 MW turbine/generator units, electrical & mechanical auxiliaries
Guangzhou – new: 4 x 306 MW turbine/air-cooled generator units, 500 rpm, electrical & mechanical auxiliaries, control system

France

Grand Maison – new: 8 x 150 MW multi-stage turbine/generator units, electrical & mechanical auxiliaries, control system

Portugal

Alqueva I – new: 2 x 120 MW turbine/generator units, electrical & mechanical equipment
Alqueva II – new: 2 x 174 MW turbine/generator units, electrical & mechanical equipment

Algeria

Beni Haroun – new: 2 x 90 MW double-stage pump/motor units, electrical & mechanical auxiliaries, control system

Morocco

Mouhac Ikli – new: 2 x 176 MW turbine/generator units, 2 x 60 MW turbine/generator units, electrical & mechanical auxiliaries, hydro-mechanical equipment, control system

Spain

La Muela – new: 3 x 250 MW generators

USA

Des Amigos – new: 3 x 26 MW turbine/generator units, 750 rpm water-cooled stators
Racoon Mountain – 6 x 50 MW, 300 rpm water-cooled stators

Brazil

Pedrares – new: 3 x 20 MW turbine/generator units, balance of plant, control system

United Kingdom

Cruachan – new: 4 x 316 MW, turbine/generator units

Grand Maison – new: 8 x 150 MW multi-stage turbine/generator units, electrical & mechanical auxiliaries, control system

Morocco

Tazighart – new: 2 x 51 MW turbines, control system

Algeria

Beni Haroun – new: 2 x 90 MW double-stage pump/motor units, electrical & mechanical auxiliaries, control system