Pumped storage

A keystone for the booming growth of renewable energies

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Variable speed pumped storage, the latest in large-scale storage technology, enables grid operators to integrate extensive wind and solar capacity, match supply to demand minute by minute and further enhance energy production efficiency throughout their fuel portfolio.

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In November 2006, 20 million European households were left in the dark following a power blackout. Within 20 minutes, Alpine dams were able to supply about 5 million homes with 5,000 MW, with the pumped storage plant of Grand'Maison, France, accounting for up to 20 %. This is a prime example of how useful pumped storage can be in balancing the grid during unplanned outages of other power plants. But that is not its only benefit.

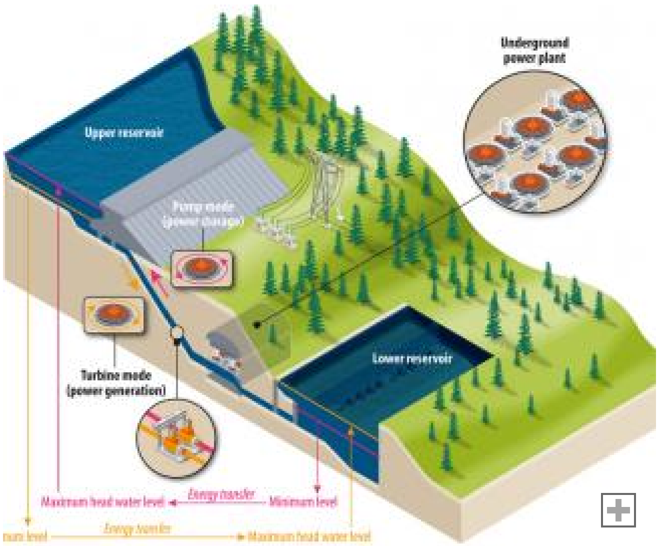
1__PSP flexibility: attractive for grid operators

Pumping water to store energy is not a new concept in itself. Pumped storage is the largest and most cost-effective means of storing energy for electricity grids, far beyond compressed air, lithium-ion and other storage technologies in use today. It is also an economically and environmentally efficient way of stabilising supply on a minute-to-minute basis. When demand is low, a

pumped storage plant (PSP) uses off-peak electricity to pump water from a lower reservoir to a higher reservoir.
Then, when demand is high, the water is released and flows down to the lower reservoir through turbines that, within seconds, generate electricity and feed it into the network. This has been done for decades, with growing efficiency: nowadays, up to 80 % of the energy consumed during the storage cycle is recovered and can be sold when demand peaks.

Double fed induction at the heart of variable speed technology
Double fed induction machines with static frequency converters feeding the rotor is the preferred architecture for motor generators in variable speed PSPs with unit outputs above 50 to 100 MW. The rotor design of double fed induction machines is significantly different from conventional synchronous machines because the rotor of a double fed induction motor generator has a three-phase rotor winding wound into a cylindrical rotor. By feeding the rotor with a low frequency AC current, a magnetic field rotating at the right speed is created to compensate for the turbine's speed variation.
As a result, it generates a magnetic field rotating at a constant speed – a fraction of the grid frequency – in the stator. This means the turbine rotation speed can be adjusted to benefit from the flywheel effect to perform fast power output or input variation or to optimise turbine or pump efficiency and regulate pumping water.

In addition, pumped storage enables utilities to operate their other energy sources at

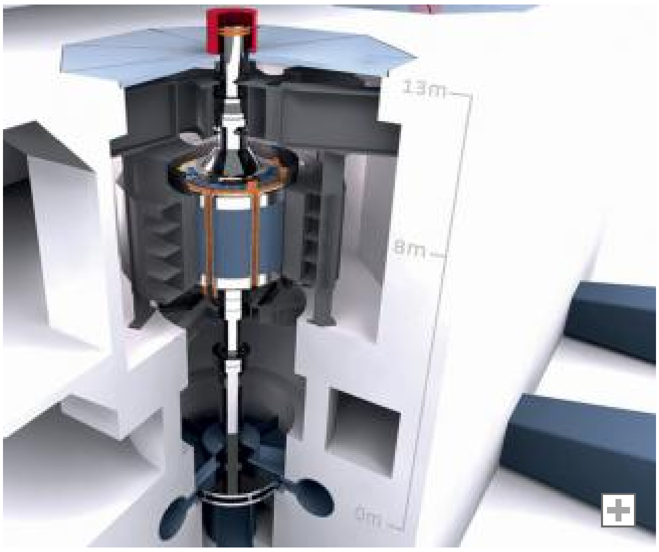


their most efficient levels, allowing fossil-fired and renewable energy sources to be run optimally. And it is precisely this last point that explains the recent boost of interest in pumped storage as part of an integrated solution to smooth out the fluctuations inevitable with increasing penetration of intermittent energy sources such as wind and solar power, since it can use their production at times of high output and low demand. “The real innovation at the heart of this growth comes from ‘variable speed’ pumped storage,” says Olivier Teller, Alstom Renewables’ PSP Product Director. “The possibility of changing the pumping power makes pumped storage plants much more flexible, which is very attractive for operators in balancing the grid.”

The grid always has to balance power generation and consumption precisely, and this balancing is harder to obtain with intermittent power sources. “So during low demand periods, variable speed pumped storage may be viewed as a much better alternative to bringing other flexible assets, such as gas plants, on line just to regulate the grid.”

To put it simply, Alstom’s variable speed technology (see sidebar) allows power plant owners to adjust the amount of energy they pump at night or when there is a light load, meaning that conventional thermal power plants that are operated for frequency adjustment can be stopped. This helps utilities operate their fleets more economically while reducing CO2 emissions. “Load balancing can be achieved using a clean, renewable energy source, replacing costly fossil fuels traditionally used for peaking," Teller points out.

2 Extending the PSP operational envelope



With an installed base of 56 GW of pump turbines and motor generators, Alstom is currently developing 6 GW of PSP projects worldwide. Three gigawatts are variable speed, and the other three are of the fixed speed type. Besides the flexibility benefit, some sites actually require variable speed, since a variable speed PSP can sustain a higher variation in the height (or head) between the water in the two reservoirs. "Challenging sites such as Nant de Drance in Switzerland and Tehri in India would have been impossible to exploit without variable speed pumps," says Teller.

All Alstom's in-house products and technologies for hydraulic turbines are designed and developed in the Global Technology Centre (GTC) in Grenoble, France. This centre manages all the product development phases, from identification of customer need to aftersales service.

In 2008, Alstom expanded the GTC, equipping its scale model test laboratory with 2 new test rigs, bringing the total number of test rigs to 6 and doubling the site's testing capacity.

With a pumped storage market expected to grow by 60 % over the next 4 years (mostly in China and Europe), the GTC is now looking forward to extending PSP operational envelopes towards more challenging conditions (1) such as very high or very low head (>800 m and <50 m), increased head range, underground and sea operation, small decentralised PSPs, etc., as well as enhancing flexibility and power range.

(1) 40 % of European PSPs are expected to be variable speed.

An extra 1,000 MW from a cavern under the Swiss Alps

Switzerland, with its mountainous landscape, is a very active producer of hydroelectricity, which represents more than half of the total energy produced in the country. The steep altitude differences in the Swiss Alps create a particularly favourable environment for the use of pumped storage power plants. In 2009, Kraftwerk Linth-Limmern AG (KLL) decided to extend its Linthal power plant in the Glarus Canton of east-central Switzerland by constructing a new underground pumped storage facility that will pump water from Lake Limmern up to Lake Mutt (which is 630 m higher, at an altitude of 2,474 m). The water is pumped through a pair of 1 km-long penstocks inclined at 45°, in order to reuse it for electricity production when needed. Alstom will provide four new 250 MW variable speed pump turbine and motor generator units. “The facility, which is installed in a giant underground cavern, will have pump and turbine capacities of 1,000 MW, boosting KLL’s output from the current 450 MW to 1,450 MW and putting it, in terms of power delivery, on a par with the Swiss Leibstadt nuclear power plant,” says Thomas Kunz, Alstom’s Global R&D Product Development Director. Many innovative components had to be developed for this project. The first units are to be installed next year, and Linthal commercial operation is due to begin in 2015.

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